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(54) Title: HIGH-STRENGTH THIN STEEL SHEET DRAWABLE AND EXCELLENT IN SHAPE FIXATION PROPERTY AND METHOD OF PRODUCING THE SAME
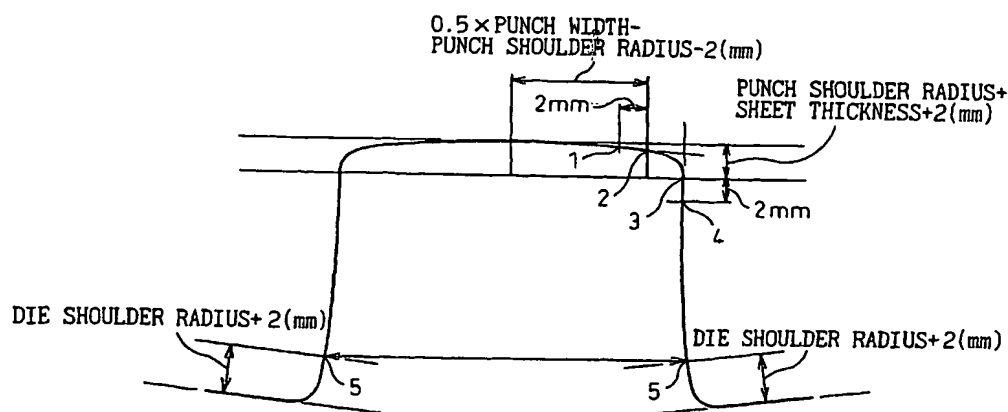
(57) Abstract: The present invention provides a high-strength thin steel sheet drawable and excellent in a shape fixation property and a method of producing the same. The present invention is a high-strength thin steel sheet drawable and excellent in a shape fixation property, characterized in that: on a plane at the center of the thickness of a steel sheet, the average ratio of the X-ray strength in the orientation component group of {100}<011> to {223}<110> to random X-ray diffraction strength is 2 or more and the average ratio of the X-ray strength in three orientation components of {554}<225>, {111}<112> and {111}<110> to random X-ray diffraction strength is 4 or less; the arithmetic average of the roughness Ra of at least one of the surfaces is 1 to 3.5 (m; the surfaces of the steel sheet are covered with a composition having a lubricating effect; and the friction coefficient of the steel sheet surfaces at 0 to 200°C is 0.05 to 0.2. Further, the present invention is a method of producing said steel sheet, characterized by: rolling a steel sheet having the chemical components specified in the present invention at a total reduction ratio of 25% or more in the temperature range of the Ar3 transformation temperature + 100°C or lower.

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

DESCRIPTION

HIGH-STRENGTH THIN STEEL SHEET DRAWABLE AND
EXCELLENT IN SHAPE FIXATION PROPERTY AND
METHOD OF PRODUCING THE SAME

Technical Field

The present invention relates to a high-strength thin steel sheet drawable and excellent in a shape fixation property, and a method of producing the steel sheet. By this invention, it is particularly possible to obtain a good drawability even with a steel sheet having a texture disadvantageous for drawing work.

Background Art

The application of aluminum alloys and other light metals and high-strength steel sheets to automobile members has expanded recently for the purpose of reducing automobile weight and thereby reducing fuel consumption and other related advantages. However, while light metals such as aluminum alloys have an advantage of high specific strength, their application is limited to special uses because they are far more costly than steel. To further reduce automobile weight, therefore, a wider application of low cost, high-strength steel sheets is strongly required.

However, when bending deformation is applied to a work piece of a high-strength steel sheet, because of the high strength, its shape after the work tends to deviate from the shape of the forming jig and return to the original shape. The phenomenon of the shape after working of a work piece returning to the original shape is called spring back. When spring back occurs, an envisaged shape is not obtained in a work piece. For this reason, high-strength steel sheets used for conventional automobile bodies have mostly been limited to those having a strength up to 440 MPa.

Although it is necessary to further reduce the

weight of a car body by the use of a high-strength steel
sheet having a high strength of 490 MPa or more, a high-
strength steel sheet showing small spring back and having
a good shape fixation property has not been made

5   available to date. Needless to say, to enhance the shape
fixation property after the working of a high-strength
steel sheet having a strength up to 440 MPa or a sheet of
a mild steel is extremely important for improving the
shape accuracy of products such as automobiles and

10   electric home appliances.

Japanese Unexamined Patent Publication No. H10-72644
discloses a cold-rolled austenitic stainless steel sheet
having a small amount of spring back (referred to as
dimensional accuracy in the present invention)

15   characterized in that the convergence of a {200} texture
in a plane parallel to the rolled surfaces is 1.5 or
more. However, the publication does not include any
description related to a technology of reducing the
phenomena of the spring back and/or the wall warping of a

20   ferritic steel sheet.

Besides the above, as a technology for reducing the
amount of spring back of a ferritic stainless steel
sheet, Japanese Unexamined Patent Publication No. 2001-
32050 discloses an invention wherein the reflected X-ray

25   strength ratio of a {100} plane parallel to the sheet
surfaces is controlled to 2 or more in the texture at the
center of the sheet thickness. However, the invention
neither refers to the reduction of wall warping nor
includes any specification regarding the orientation

30   component group of {100}<011> to {223}<110> and the
orientation component {112}<110>, which is an important
orientation component for reducing the wall warping.

Further, WO No. 00/06791 discloses a ferritic thin
steel sheet wherein the ratio of reflected X-ray strength

35   of a {100} plane to that of a {111} plane is controlled
to 1 or more for the purpose of improving the shape
fixation property. However, unlike the present

invention, this invention does not refer to the ratios of the X-ray strength in the orientation component group of {100}<011> to {223}<110> to the random X-ray diffraction strength and those in the orientation components of

5 {554}<225>, {111}<112> and {111}<110> to the random X-ray diffraction strength, and, in addition, there is no disclosure on the technology of improving drawability.

Japanese Unexamined Patent Publication No. 2001-64750 discloses a cold-rolled steel sheet wherein, as a

10 technology for reducing the amount of spring back, the reflected X-ray strength ratio of a {100} plane parallel to sheet surfaces is controlled to 3 or more. However, this invention is characterized by specifying the reflected X-ray strength ratio of a {100} plane on a very

15 surface of a steel sheet, and the position of X-ray measurement is different from the position specified in the present invention, where the average X-ray strength ratio in the orientation component group of {100}<011> to {223}<110> is measured at the center of the thickness of

20 a steel sheet. Besides, this invention neither refers to the orientation components of {554}<225>, {111}<112> and {111}<110>, nor discloses any technology of improving drawability.

Further, as a steel sheet excellent in a shape

25 fixation property, Japanese Unexamined Patent Publication No. 2000-297349 discloses a hot-rolled steel sheet wherein the absolute value of the in-plane anisotropy of r-value Δr is controlled to 0.2 or less. However, this invention is characterized by improving a shape fixation

30 property by lowering a yield ratio, and it does not include any description regarding the control of a texture aiming at improving a shape fixation property based on the philosophy described in the present invention.

35 In such a situation, the present invention relates to a high-strength thin steel sheet drawable and excellent in a shape fixation property for obtaining a

good drawability even with a steel sheet having a texture disadvantageous for drawing work, and a method of producing the same. In other words, the object of the present invention is to provide a high-strength thin steel sheet excellent in a shape fixation property and drawability, and a method of producing said steel sheet economically and stably.

Disclosure of the Invention

The inventors of the present invention, in consideration of the production processes of high-strength thin steel sheets presently produced on an industrial scale using generally employed production facilities, earnestly studied how to obtain a high-strength thin steel sheet having both a good shape fixation property and a high drawability simultaneously.

As a result, the present invention has been established based on a new discovery that the following conditions are very effective for securing both a good shape fixation property and a high drawability at the same time: at least on a plane at the center of the thickness of a steel sheet, the average ratio of the X-ray strength in the orientation component group of {100}<011> to {223}<110> to random X-ray diffraction strength is 3.0 or more and the average ratio of the X-ray strength in the three orientation components of {554}<225>, {111}<112> and {111}<110> to random X-ray diffraction strength is 3.5 or less; a composition having a lubricating effect is applied to a steel sheet wherein an arithmetic average of roughness Ra of at least one of the surfaces is 1 to 3.5 μm; and the friction coefficient of the steel sheet surfaces at 0 to 200°C is 0.05 to 0.2.

The gist of the present invention, therefore, is as follows:

(1) A high-strength thin steel sheet drawable and excellent in a shape fixation property, characterized in that: at least on a plane at the center of the thickness

of a steel sheet, the average ratio of the X-ray strength in the orientation component group of {100}<011> to {223}<110> to random X-ray diffraction strength is 3 or more and the average ratio of the X-ray strength in three orientation components of {554}<225>, {111}<112> and {111}<110> to random X-ray diffraction strength is 3.5 or less; the arithmetic average of the roughness Ra of at least one of the surfaces is 1 to 3.5 μm; and the surfaces of the steel sheet are covered with a composition having a lubricating effect.

(2) A high-strength thin steel sheet drawable and excellent in a shape fixation property according to the item (1), characterized in that the friction coefficient of the steel sheet surfaces at 0 to 200°C is 0.05 to 0.2.

(3) A high-strength thin steel sheet drawable and excellent in a shape fixation property according to the item (1) or (2), characterized in that the microstructure of the steel sheet is a compound structure containing ferrite as the phase accounting for the largest volume percentage and martensite mainly as the second phase.

(4) A high-strength thin steel sheet drawable and excellent in a shape fixation property according to the item (1) or (2), characterized in that the microstructure of the steel sheet is a compound structure containing retained austenite by 5 to 25% in terms of volume percentage and having the balance mainly consisting of ferrite and bainite.

(5) A high-strength thin steel sheet drawable and excellent in a shape fixation property according to the item (1) or (2), characterized in that the microstructure of the steel sheet is a compound structure containing bainite or ferrite and bainite as the phase accounting for the largest volume percentage.

　　　　(6) A high-strength thin steel sheet drawable and
excellent in a shape fixation property according to any
one of the items (1) to (5), characterized by containing,
5　　in mass,
C: 0.01 to 0.3%,
Si: 0.01 to 2%,
Mn: 0.05 to 3%,
P: 0.1% or less,
10　　S: 0.01% or less, and
Al: 0.005 to 1%,
with the balance consisting of Fe and unavoidable
impurities.

15　　　　(7) A high-strength thin steel sheet drawable and
excellent in a shape fixation property according to the
item (6), characterized by further containing, in mass,
Ti: 0.05 to 0.5% and/or
Nb: 0.01 to 0.5%.
20

　　　　(8) A high-strength thin steel sheet drawable and
excellent in a shape fixation property according to the
item (1) or (2), characterized by containing, in mass,
C: 0.01 to 0.1%,
25　　S: 0.03% or less,
N: 0.005% or less, and
Ti: 0.05 to 0.5%,
so as to satisfy the following expression:
　　　Ti - (48/12)C - (48/14)N - (48/32)S ≧ 0%,
30　　with the balance consisting of Fe and unavoidable
impurities.

　　　　(9) A high-strength thin steel sheet drawable and
excellent in a shape fixation property according to the
35　　item (1) or (2), characterized in that the steel is a
steel according to the item (8) further containing, in
mass,

Nb: 0.01 to 0.5%, and

Ti, so as to satisfy the following expression:

$$Ti + (48/93)Nb - (48/12)C - (48/14)N - (48/32)S \geqq 0\%,$$

5   with the balance consisting of Fe and unavoidable
impurities.

(10) A high-strength thin steel sheet drawable and
excellent in a shape fixation property, characterized in
10   that the steel is a steel according to the item (8) or
(9) further containing, in mass,

Si: 0.01 to 2%,

Mn: 0.05 to 3%,

P: 0.1% or less, and
15   Al: 0.005 to 1%.

(11) A high-strength thin steel sheet drawable and
excellent in a shape fixation property according to any
one of the items (6) to (10), characterized by further
20   containing, in mass,

B: 0.0002 to 0.002%.

(12) A high-strength thin steel sheet drawable and
excellent in a shape fixation property according to any
25   one of the items (6) to (11), characterized by further
containing, in mass,

Cu: 0.2 to 2%.

(13) A high-strength thin steel sheet drawable and
30   excellent in a shape fixation property according to any
one of the items (6) to (12), characterized by further
containing, in mass,

Ni: 0.1 to 1%.

35   (14) A high-strength thin steel sheet drawable and
excellent in a shape fixation property according to any
one of the items (6) to (13), characterized by further

containing, in mass,

Ca: 0.0005 to 0.002% and/or

REM: 0.0005 to 0.02%.

(15) A high-strength thin steel sheet drawable and excellent in a shape fixation property according to any one of the items (6) to (14), characterized by further containing, in mass, one or more of

Mo: 0.05 to 1%,

V: 0.02 to 0.2%,

Cr: 0.01 to 1%, and

Zr: 0.02 to 0.2%.

(16) A high-strength thin steel sheet drawable and excellent in a shape fixation property according to any one of the items (1) to (15), characterized by having a zinc plating layer between the steel sheet and a composition having a lubricating effect.

(17) A method of producing a high-strength thin steel sheet drawable and excellent in a shape fixation property, characterized by: in a hot rolling process for obtaining a high-strength thin steel sheet having the chemical components according to any one of the items (6), (7) and (11) to (15), subjecting a slab having said chemical components to rough rolling and, then, to finish rolling at a total reduction ratio of 25% or more in terms of steel sheet thickness in the temperature range of the Ar_3 transformation temperature + 100°C or lower; and, thereafter, applying a composition having a lubricating effect to the surfaces of the steel sheet.

(18) A method of producing a high-strength thin steel sheet drawable and excellent in a shape fixation property according to the item (3), characterized by: in a hot rolling process for obtaining a high-strength thin steel sheet having the chemical components according to

any one of the items (6), (7) and (11) to (15),
subjecting a slab having said chemical components to
rough rolling and, then, to finish rolling at a total
reduction ratio of 25% or more in terms of steel sheet
thickness in the temperature range of the Ar_3
transformation temperature + 100°C or lower, retaining
the hot-rolled steel sheet thus produced for 1 to 20 sec.
in the temperature range from the Ar_1 transformation
temperature to the Ar_3 transformation temperature, then,
cooling it at a cooling rate of 20°C/sec. or more, and
coiling it at a coiling temperature of 350°C or lower;
and, thereafter, applying a composition having a
lubricating effect to the surfaces of the steel sheet.

(19) A method of producing a high-strength thin
steel sheet drawable and excellent in a shape fixation
property according to the item (4), characterized by: in
a hot rolling process for obtaining a high-strength thin
steel sheet having the chemical components according to
any one of the items (6), (7) and (11) to (15),
subjecting a slab having said chemical components to
rough rolling and, then, to finish rolling at a total
reduction ratio of 25% or more in terms of steel sheet
thickness in the temperature range of the Ar_3
transformation temperature + 100°C or lower, retaining
the hot-rolled steel sheet thus produced for 1 to 20 sec.
in the temperature range from the Ar_1 transformation
temperature to the Ar_3 transformation temperature, then,
cooling it at a cooling rate of 20°C/sec. or more, and
coiling it at a coiling temperature in the range from
over 350°C to below 450°C; and, thereafter, applying a
composition having a lubricating effect to the surfaces
of the steel sheet.

(20) A method of producing a high-strength thin
steel sheet drawable and excellent in a shape fixation
property according to the item (5), characterized by: in

a hot rolling process for obtaining a high-strength thin
steel sheet having the chemical components according to
any one of the items (6), (7) and (11) to (15),
subjecting a slab having said chemical components to
5   rough rolling and, then, to finish rolling at a total
reduction ratio of 25% or more in terms of steel sheet
thickness in the temperature range of the Ar_3
transformation temperature + 100°C or lower, then,
cooling it at a cooling rate of 20°C/sec. or more, and
10   coiling it at a coiling temperature of 450°C or more;
and, thereafter, applying a composition having a
lubricating effect to the surfaces of the steel sheet.

        (21) A method of producing a high-strength thin
15   steel sheet drawable and excellent in a shape fixation
property, characterized by: in a hot rolling process for
obtaining a thin steel sheet having the chemical
components according to any one of the items (8) to (15),
subjecting a slab having said chemical components to
20   rough rolling and, then, to finish rolling at a total
reduction ratio of 25% or more in terms of steel sheet
thickness in the temperature range of the Ar_3
transformation temperature + 100°C or lower, and then,
cooling and coiling the steel sheet thus produced; and,
25   thereafter, applying a composition having a lubricating
effect.

        (22) A method of producing a high-strength thin
steel sheet drawable and excellent in a shape fixation
30   property according to any one of the items (17) to (21),
characterized by, in a hot rolling process, applying
lubrication rolling to the finish rolling after the rough
rolling.

35   (23) A method of producing a high-strength thin
steel sheet drawable and excellent in a shape fixation
property according to any one of the items (17) to (22),

characterized by, in a hot rolling process, applying
descaling after the completion of the rough rolling.

        (24) A method of producing a high-strength thin
5   steel sheet drawable and excellent in a shape fixation
        property, characterized by: in producing a high-strength
        thin steel sheet having the chemical components according
        to any one of the items (6), (7) and (11) to (15),
        subjecting a slab having said chemical components to,
10   sequentially, hot rolling, pickling, cold rolling at a
        reduction ratio below 80% in terms of steel sheet
        thickness, and then applying a heat treatment comprising
        the processes of retaining the cold-rolled steel sheet
        for 5 to 150 sec. in the temperature range from the
15   recovery temperature to the Ac_3 transformation
        temperature + 100°C and then cooling it; and, thereafter,
        applying a composition having a lubricating effect to the
        surfaces of the steel sheet.

20   (25) A method of producing a high-strength thin
        steel sheet drawable and excellent in a shape fixation
        property according to the item (3), characterized by: in
        producing a high-strength thin steel sheet having the
        chemical components according to any one of the items
25   (6), (7) and (11) to (15), subjecting a slab having said
        chemical components to, sequentially, hot rolling,
        pickling, cold rolling at a reduction ratio below 80% in
        terms of steel sheet thickness, and then applying a heat
        treatment comprising the processes of retaining the cold-
30   rolled steel sheet for 5 to 150 sec. in the temperature
        range from the Ac_1 transformation temperature to the Ac_3
        transformation temperature + 100°C and then cooling it at
        a cooling rate of 20°C/sec. or more to the temperature
        range of 350°C or lower; and, thereafter, applying a
35   composition having a lubricating effect to the surfaces
        of the steel sheet.

(26) A method of producing a high-strength thin
steel sheet drawable and excellent in a shape fixation
property according to the item (4), characterized by: in
producing a high-strength thin steel sheet having the
5   chemical components according to any one of the items
(6), (7) and (11) to (15), subjecting a slab having said
chemical components to, sequentially, hot rolling,
pickling, cold rolling at a reduction ratio below 80% in
terms of steel sheet thickness, and then applying a heat
10   treatment comprising the processes of retaining the cold-
rolled steel sheet for 5 to 150 sec. in the temperature
range from the Ac_1 transformation temperature to the Ac_3
transformation temperature + 100°C, cooling it at a
cooling rate of 20°C/sec. or more to the temperature
15   range from above 350°C to below 450°C, retaining it again
in this temperature range for 5 to 600 sec., and then
cooling it again at a cooling rate of 5°C/sec. or more to
the temperature range of 200°C or lower; and, thereafter,
applying a composition having a lubricating effect to the
20   surfaces of the steel sheet.

(27) A method of producing a high-strength thin
steel sheet drawable and excellent in a shape fixation
property according to the item (5), characterized by: in
25   producing a high-strength thin steel sheet having the
chemical components according to any one of the items
(6), (7) and (11) to (15), subjecting a slab having said
chemical components to, sequentially, hot rolling,
pickling, cold rolling at a reduction ratio below 80% in
30   terms of steel sheet thickness, and then applying a heat
treatment comprising the processes of retaining the cold-
rolled steel sheet for 5 to 150 sec. in the temperature
range from the Ac_1 transformation temperature to the Ac_3
transformation temperature + 100°C and then cooling it;
35   and, thereafter, applying a composition having a
lubricating effect to the surfaces of the steel sheet.

(28) A method of producing a high-strength thin steel sheet drawable and excellent in a shape fixation property, characterized by: for producing a thin steel sheet having the chemical components according to any one of the items (8) to (15), subjecting a slab having said chemical components to, sequentially, hot rolling, pickling, cold rolling at a reduction ratio below 80% in terms of steel sheet thickness, and then applying a heat treatment comprising the processes of retaining the cold-rolled steel sheet for 5 to 150 sec. in the temperature range from the recovery temperature to the Ac_3 transformation temperature + 100°C and then cooling it; and, thereafter, applying a composition having a lubricating effect.

(29) A method of producing a high-strength thin steel sheet drawable and excellent in a shape fixation property according to any one of the items (17) to (23), characterized by: galvanizing the surfaces of the steel sheet by dipping the steel sheet in a zinc plating bath after hot rolling; and, thereafter, applying a composition having a lubricatirg effect to the surfaces of the steel sheet.

(30) A method of producing a high-strength thin steel sheet drawable and excellent in a shape fixation property according to any one of the items (24) to (28), characterized by: galvanizing the surfaces of the steel sheet by dipping the steel sheet in a zinc plating bath after the completion of the heat treatment processes; and, thereafter, applying a composition having a lubricating effect to the surfaces of the steel sheet.

(31) A method of producing a high-strength thin steel sheet drawable and excellent in a shape fixation property, characterized by: subjecting a steel sheet to an alloying treatment after the galvanizing by dipping

the steel sheet in a zinc plating bath according to the
item (29) or (30); and, thereafter, applying a
composition having a lubricating effect to the surfaces
of the steel sheet.

5

Brief Description of the Drawings
        Fig. 1 is a schematic illustration showing the
sectional shape of a sample having undergone a bending
test.

10   Fig. 2 is an illustration explaining a friction
coefficient measuring apparatus.

Best Mode for Carrying out the Invention
        First, the present invention according to the item

15 (1) or (2) will be explained in detail.
        For realizing an excellent shape fixation property,
it is necessary that the average of the ratio of the X-
ray strength in the orientation component group of
$\{100\}<011>$ to $\{223\}<110>$ to random X-ray diffraction

20 strength on a plane at the center of the thickness of a
steel sheet be 3 or more. If it is below 3, the shape
fixation property becomes poor.
        Here, the average ratio of the X-ray strength in the
orientation component group of $\{100\}<011>$ to $\{223\}<110>$

25 to random X-ray diffraction strength is obtained from the
three-dimensional texture obtained by calculating the X-
ray diffraction strengths in the principal orientation
components included in the orientation component group,
namely $\{100\}<011>$, $\{116\}<110>$, $\{114\}<110>$, $\{113\}<110>$,

30 $\{112\}<110>$, $\{335\}<110>$ and $\{223\}<110>$, either by the
vector method based on the pole figure of $\{110\}$, or by
the series expansion method using two or more (desirably,
three or more) pole figures out of the pole figures of
$\{110\}$, $\{100\}$, $\{211\}$ and $\{310\}$.

35   For example, as the ratio of the X-ray strength in
the above crystal orientation components to random X-ray
diffraction strength calculated by the latter method, the

strengths of (001)[1-10], (116)[1-10], (114)[1-10], (113)[1-10], (112)[1-10], (335)[1-10] and (223)[1-10] at a $\phi2 = 45°$ cross section in a three-dimensional texture can be used without modification. Note that the average

5   ratio of the X-ray strength in the orientation component group of {100}<011> to {223}<110> to random X-ray diffraction strength is the arithmetic average ratio of all the above orientation components. When it is impossible to obtain the strengths in all these

10   orientation components, the arithmetic average of the strengths in the orientation components of {100}<011>, {116}<110>, {114}<110>, {112}<110> and {223}<110> may be used as a substitute.

In addition to the above, it is necessary that the

15   average ratio of the X-ray strength in the following three orientation components, namely {554}<225>, {111}<112> and {111}<110>, to random X-ray diffraction strength be 3.5 or less. When it exceeds 3.5, even if the average ratio of the X-ray strength in the

20   orientation component group of {100}<011> to {223}<110> to random X-ray diffraction strength is within the appropriate range, a good shape fixation property is not obtained. Here, the average ratio of the X-ray strength in the three orientation components of {554}<225>,

25   {111}<112> and {111}<110> to random X-ray diffraction strength can be calculated from the three-dimensional texture obtained in the same manner as explained above. It is preferable in the present invention that the average ratio of the X-ray strength in the orientation

30   component group of {100}<011> to {223}<110> to random X-ray diffraction strength be 4 or more, and that the arithmetic average ratio of the X-ray strength in the orientation components of {554}<225>, {111}<112> and {111}<110> to random X-ray diffraction strength be below

35   2.5.

The reason why the X-ray strengths in the crystal orientation components are important for a shape fixation

property in bending work is not altogether clear, but it
is estimated that the sliding behavior of crystals during
bending deformation has some connection.

5   A specimen for an X-ray diffraction measurement is
prepared by cutting out a test piece 30 mm in diameter
from a position of 1/4 or 3/4 of the width of a steel
sheet, grinding the surfaces up to the three-triangle
grade finish (the second finest finish) and, then,
removing strain by chemical polishing or electrolytic
10   polishing. Note that a crystal orientation component
expressed as {hkl}<uvw> means that the direction of a
normal to the plane of a steel sheet is parallel to <hkl>
and the rolling direction of the steel sheet is parallel
to <uvw>. The measurement of a crystal orientation with
15   X-ray is conducted, for example, in accordance with the
method described in pages 274 to 296 of the Japanese
translation of Elements of X-ray Diffraction by B. D.
Cullity (published in 1986 from AGNE Gijutsu Center,
translated by Gentaro Matsumura).

20   Next, the surface conditions of a steel sheet, which
are important in the present invention for securing good
drawability, are explained. In the present invention,
the arithmetic average of roughness Ra of at least one of
the surfaces of a steel sheet before the steel sheet is
25   coated with a composition having a lubricating effect is
determined to be from 1 to 3.5 μm. When the arithmetic
average of roughness Ra is below 1 μm, it becomes
difficult to retain on the steel sheet surface a
composition having a lubricating effect to be applied
30   later. When the arithmetic average of roughness Ra
exceeds 3.5 μm, on the other hand, a sufficient
lubricating effect cannot be obtained even after a
composition having a lubricating effect is applied. For
this reason, the arithmetic average of roughness Ra of at
35   least one of the surfaces of a steel sheet is determined
to be from 1 to 3.5 μm. A preferable range is from 1 to

3 μm. Here, the arithmetic average of roughness Ra is an
arithmetic average of roughness Ra specified in Japanese
Industrial Standard (JIS) B 0601-1994.

In addition to the above, in the present invention,
the friction coefficient of a steel sheet after the
application of a composition having a lubricating effect
is determined to be 0.05 to 0.2 at 0 to 200°C in the
direction of rolling and/or in the direction
perpendicular to the rolling direction. When a friction
coefficient is below 0.05, even if blank holding force
(BHF) is increased during press forming for improving a
shape fixation property, a steel sheet is not held at its
brim and the material flows into a die, deteriorating the
shape fixation property. When a friction coefficient
exceeds 0.2, on the other hand, the flow of a steel sheet
into a die is decreased even if the BHF is lowered within
a practical tolerance, probably leading to the
deterioration of drawing workability. For this reason,
the friction coefficient of at least one of the
directions must be 0.05 to 0.2.

As for the temperature range in which the value of a
friction coefficient is prescribed, if a friction
coefficient is measured at below 0°C, an adequate
evaluation is impossible because of frost and so on
forming on a steel sheet surface. If the temperature is
above 200°C, a composition having a lubricating effect
applied to the surfaces of a steel sheet may become
unstable. For this reason, the temperature range in
which the value of a friction coefficient is prescribed
is determined to be from 0 to 200°C.

Here, a friction coefficient is defined as the ratio
(f/F) of a drawing force (f) to a pressing force (F) in
the following test procedures: a composition having a
lubricating effect is applied to the surfaces of a
subject steel sheet to be evaluated; the steel sheet is
placed between two flat plates having a Vickers hardness
of Hv600 or more at the surfaces; a force (F)

perpendicular to the surfaces of the subject steel sheet
is imposed so that the contact stress is 1.5 to 2
kgf/mm^2; and the force (f) required for pulling out the
subject steel sheet from between the flat plates is

5   measured.

Then, an index of drawability of a steel sheet is
defined as the quotient (D/d) obtained by dividing the
maximum diameter (D) in which drawing has been successful
by the diameter (d) of a cylindrical punch when a steel

10   sheet is formed into a disc-shape and subjected to
drawing work using the cylindrical punch. In this test,
steel sheets are formed into various disc-shapes 300 to
400 mm in diameter and a cylindrical punch 175 mm in
diameter having a shoulder 10 mm in radius around the

15   bottom face and a die having a shoulder 15 mm in radius
are used in the evaluation of drawability.

The microstructure of a steel sheet according to the
present invention is explained hereafter.

20   First, the present invention according to the items
(3) to (5) is explained in detail.

In the present invention, it is not necessary to
specify the microstructure of a steel sheet for the
purpose of improving a shape fixation property; the

25   effect of the present invention on improving a shape
fixation property is obtained as far as a texture falling
within the range of the present invention (the ratios of
the X-ray strength in specific orientation components to
random X-ray diffraction strength within the ranges of

30   the present invention) is obtained in the structures of
ferrite, bainite, pearlite and/or martensite formed in
commonly used steel materials. Further, stretch
formability and other press forming properties can be
enhanced, when a specific microstructure, for example, a

35   compound structure containing retained austenite by 5 to
25% in terms of volume percentage and having the balance
mainly consisting of ferrite and bainite, a compound

structure containing ferrite as the phase accounting for the largest volume percentage and martensite mainly as the second phase, or the like, is formed.

Note that, when a structure which is not a bcc
5   crystal structure, such as retained austenite, is included in a compound structure composed of two or more phases, such a compound structure does not pose any problem insofar as the ratios of the X-ray strength in the orientation components and orientation component
10   groups to random X-ray diffraction strength converted by the volume percentage of the other structures are within the respective ranges of the present invention.

Besides, pearlite containing coarse carbides may act as a starting point of a fatigue crack, remarkably
15   deteriorating fatigue strength, and, for this reason, it is desirable that the volume percentage of the pearlite containing coarse carbides be 15% or less. When yet better fatigue properties are required, it is desirable that the volume percentage of the pearlite containing
20   coarse carbides be 5% or less.

Here, the volume percentage of ferrite, bainite, pearlite, martensite or retained austenite is defined as the area percentage in a microstructure at a position in the depth of 1/4 of the steel sheet thickness, obtained
25   by: polishing a test piece, which is cut out from a position of 1/4 or 3/4 of the width of a steel sheet, along the section surface in the rolling direction; etching the section surface with nitral reagent and/or the reagent disclosed in Japanese Unexamined Patent
30   Publication No. H5-163590; and then observing the etched surface with a light-optical microscope under a magnification of 200 to 500. Since it is sometimes difficult to identify retained austenite by the etching with the above reagents, the volume percentage may be
35   calculated in the following manner.

Because the crystal structure of austenite is different from that of ferrite, they can be easily

distinguished crystallographically. Therefore, the
volume percentage of retained austenite can be obtained
by the X-ray diffraction method too, namely by the
simplified method of calculating the volume percentage by
5   the following equation based on the difference between
austenite and ferrite in the reflection intensity of
their lattice planes using the Kα ray of Mo:

$$V\gamma = (2/3)\{100/(0.7 \times \alpha(211)/\gamma(220) + 1)\} +$$

$$(1/3)\{100/(0.78 \times \alpha(211)/\gamma(311) + 1)\},$$

10 where, $\alpha(211)$, $\gamma(220)$ and $\gamma(311)$ are the X-ray reflection
intensity values of the indicated lattice planes of
ferrite (α) and austenite (γ), respectively.

In order to obtain a low yield ratio for realizing a
better shape fixation property than the once improved
15 shape fixation property in the present invention, it is
necessary that the microstructure of a steel sheet is a
compound structure containing ferrite as the phase
accounting for the largest volume percentage and
martensite mainly as the second phase. Here, the present
20 invention allows containing unavoidably included bainite,
retained austenite and pearlite if their total percentage
is below 5%. Note that, for securing a low yield ratio
of 70% or less, it is desirable that the volume
percentage of ferrite be 50% or more.

25 In order to obtain a good ductility, in addition to
improving a shape fixation property, in the present
invention, it is necessary that the microstructure of a
steel sheet is a compound structure containing retained
austenite by 5% to 25% in terms of volume percentage and
30 having the balance mainly consisting of ferrite and
bainite. Here, the present invention allows containing
unavoidably included martensite and pearlite if their
total percentage is below 5%.

Further, in order to obtain a good burring
35 workability, in addition to improving a shape fixation

property, in the present invention, it is necessary that the microstructure of a steel sheet is a compound structure containing bainite or ferrite and bainite as the phase accounting for the largest volume percentage.

5   Here, the present invention allows containing unavoidably included martensite, retained austenite and pearlite. In order to obtain a good burring workability (a hole expansion ratio), it is desirable that the total volume percentage of hard retained austenite and martensite be

10   below 5%. It is also desirable that the volume percentage of bainite be 30% or more. Further, for realizing a good ductility, it is desirable that the volume percentage of bainite be 70% or less.

Next, the present invention according to any one of

15   the items (8) – (10) is explained in detail.

In order to obtain a better burring workability, in addition to improving a shape fixation property, in the present invention, it is desirable that the microstructure of a steel sheet consists of a single

20   phase of ferrite for securing a good burring workability (a hole expansibility). Here, the present invention allows some amount of bainite to be contained as occasion demands. Further, in order to secure a yet better burring workability, it is desirable that the volume

25   percentage of bainite be 10% or less. Here, the present invention allows containing unavoidably included martensite, retained austenite and pearlite. The ferrite mentioned here includes bainitic ferrite and acicular ferrite structures. Further, in order to secure good

30   fatigue properties, it is desirable that the volume percentage of pearlite containing coarse carbides be 5% or less. Additionally, in order to secure a good burring workability (a hole expansibility), it is desirable that the total volume percentage of retained austenite and

35   martensite be below 5%.

Next, the reasons why the chemical components are

limited in the present invention are explained.

The present invention according to the items (6) to (15) is explained in detail.

C is an indispensable element for obtaining a desired microstructure. When C content exceeds 0.3%, however, workability is deteriorated and, for this reason, the content is set at 0.3% or less. Additionally, when C content exceeds 0.2%, weldability is deteriorated and, for this reason, it is desirable that the content be 0.2% or less. On the other hand, when the content of C is below 0.01%, steel strength decreases and, therefore, the content is set at 0.01% or more. Further, in order to obtain retained austenite stably in an amount sufficient for realizing a good ductility, it is desirable that the content be 0.05% or more.

In addition, in relation to any one of the items (8) – (10) in particular, when the content of C exceeds 0.1%, workability and weldability are deteriorated, and, therefore, the content is set at 0.1% or less. When the content is below 0.01%, steel strength is lowered and, for this reason, its content is set at 0.01% or more.

Si is a solute strengthening element and, as such, it is effective for enhancing strength. Its content has to be 0.01% or more for obtaining a desired strength but, when it is contained in excess of 2%, workability is deteriorated. The Si content, therefore, is determined to be from 0.01 to 2%.

Mn is a solute strengthening element and, as such, it is effective for enhancing strength. Its content has to be 0.05% or more for obtaining a desired strength. In the case where elements such as Ti, which suppress the occurrence of hot cracking induced by S, are not added in a sufficient amount in addition to Mn, it is desirable to add Mn so that the expression $Mn/S \geqq 20$ is satisfied in terms of mass percentage. Further, Mn is an element to stabilize austenite and, therefore, in order to stably

obtain a sufficient amount of retained austenite for realizing a good ductility, it is desirable that its addition amount be 0.1% or more. When Mn is added in excess of 3%, on the other hand, cracks occur to slabs. Thus, the content is set at 3% or less.

P is an undesirable impurity, and the lower its content the better. When the content exceeds 0.1%, workability and weldability are adversely affected, and so are fatigue properties. Therefore, P content is set at 0.1% or less.

S causes cracks to occur during hot rolling when contained too much and, therefore, the content must be controlled as low as possible, but the content up to 0.03% is permissible. S is also an impurity and the lower its content the better. When S content is too large, the A type inclusions detrimental to local ductility and burring workability are formed and, for this reason, the content has to be minimized. A desirable content of S is, therefore, 0.01% or less.

Al is required to be added by 0.005% or more for deoxidizing molten steel, but its upper limit is set at 1.0% for avoiding cost increase. Al increases the formation of non-metallic inclusions and deteriorates elongation when added excessively and, for this reason, a desirable content of Al is 0.5% or less.

N, in relation to any one of the items (8) ~ (10) in particular, combines with Ti and Nb and forms precipitates at a temperature higher than C does, and, by so doing, decreases the amounts of Ti and Nb which are effective for fixing C. For this reason, N content must be minimized. A permissible content of N is 0.005% or less.

Ti contributes to the increase of the strength of a steel sheet through precipitation strengthening. When the content is below 0.05%, however, the effect is insufficient and, when the content exceeds 0.5%, not only the effect is saturated but also the cost of alloy

addition is increased. For this reason, the content of Ti is determined to be from 0.05 to 0.5%.

In addition, in relation to any one of the items (8) ~ (10) in particular, Ti is one of the most important elements in the present invention. That is, in order to precipitate and fix C, which forms carbides such as cementite detrimental to burring workability, and thereby contribute to the improvement of burring workability, it is necessary that the condition, Ti - (48/12)C - (48/14)N - (48/32)S ≧ 0%, be satisfied.

Here, since S and N combine with Ti to form precipitates at a temperature comparatively higher than C does, in order to satisfy the expression Ti ≧ 48/12C, the condition, Ti - (48/12)C - (48/14)N - (48/32)S ≧ 0%, must be satisfied inevitably.

Nb contributes to the improvement of the strength of a steel sheet through precipitation strengthening, like Ti does. It also has an effect to improve burring workability by making crystal grains fine. When the content is below 0.01%, however, the effects do not show up sufficiently and, if the content exceeds 0.5%, not only the effects are saturated but also the cost of alloy addition is increased. For this reason, the content of Nb is determined to be from 0.01 to 0.5%.

In addition, in relation to the item (9) or (10) in particular, in order to precipitate and fix C, which forms carbides such as cementite detrimental to burring workability, and thereby contribute to the improvement of burring workability, it is necessary that the condition, Ti + (48/93)Nb - (48/12)C - (48/14)N - (48/32)S ≧ 0%, be satisfied.

Here, since Nb forms carbides at a temperature comparatively lower than Ti does, in order to satisfy the expression Ti + 48/93Nb ≧ 48/12C, the condition, Ti + (48/93)Nb - (48/12)C - (48/14)N - (48/32)S ≧ 0%, must be

satisfied inevitably.

Cu is added as occasion demands, since it has an effect to improve fatigue properties when it is in the state of solid solution. However, a tangible effect is not obtained when the addition amount is below 0.2%, but the effect is saturated when the content exceeds 2%. Thus, the range of the Cu content is determined to be from 0.2 to 2%. It has to be noted that, when the coiling temperature is 450°C or higher, if Cu is contained in excess of 1.2%, it may precipitate after coiling, drastically deteriorating workability. For this reason, it is desirable that the content of Cu be limited to 1.2% or less.

B is added as occasion demands, since it has an effect to raise fatigue limit when added in combination with Cu. Further, in relation to the item (8), (9) or (10) in particular, B is added as occasion demands, since it has an effect to raise fatigue limit by suppressing the intergranular embrittlement caused by P, which is considered to result from a decrease in the amount of solute C. An addition of B by below 0.0002% is not enough for obtaining the effects but, when B is added in excess of 0.002%, cracks occur to a slab. For this reason, the addition amount of B is determined to be from 0.0002 to 0.002%.

Ni is added as occasion demands for preventing hot shortness caused by containing Cu. An addition amount of below 0.1% is not enough for obtaining the effect but, when Ni is added in excess of 1%, the effect is saturated. For this reason, the content is determined to be from 0.1 to 1%. Note that, when the content of Cu is 1.2% or less, it is desirable that the content of Ni be 0.6% or less.

Ca and REM are the elements to modify the shape of non-metallic inclusions, which serve as starting points of fractures and/or deteriorate workability, and to render them harmless. But a tangible effect is not

obtained when either of them is added by below 0.0005%.
When Ca is added in excess of 0.002% or REM in excess of
0.02%, the effect is saturated. Thus, it is desirable to
add Ca by 0.0005 to 0.002% and REM by 0.0005 to 0.02%.

Additionally, one or more of precipitation
strengthening elements and solute strengthening elements,
namely Mo, V, Cr and Zr, may be added for enhancing
strength. However, when they are added by below 0.05%,
0.02%, 0.01% and 0.02%, respectively, no tangible effects
show up and, when they are added in excess of 1%, 0.2%,
1% and 0.2%, respectively, the effects are saturated.

Sn, Co, Zn, W and/or Mg may be added by 1% or less
in total to a steel mainly consisting of the components
explained above, but, since Sn may cause surface defects
during hot rolling, it is preferable to limit the content
of Sn to 0.05% or less.

Now, the reasons for limiting the conditions of the
production method according to the present invention are
hereafter described in detail.

A steel sheet according to the present invention can
be produced through the processes of: casting; hot
rolling and cooling, or hot rolling, cooling, pickling
and cold rolling; then, heat treatment or heat treatment
of a hot-rolled or cold-rolled steel sheet in a hot dip
plating line; and further surface treatment applied to a
steel sheet thus produced separately as occasion demands.

The present invention does not particularly specify
the production methods prior to hot rolling. That is: a
steel may be melted and refined by a blast furnace, an
electric arc furnace or the like; then the chemical
components may be adjusted so as to contain desired
amounts of the components in one or more of various
secondary refining processes; and then the steel may be
cast into a slab through a casting process such as an
ordinary continuous casting process, an ingot casting
process and a thin slab casting process. Steel scraps

may be used as a raw material. Further, in the case of a
slab cast through a continuous casting process, the slab
may be fed to a hot-rolling mill directly while it is
hot, or after cooling it to the room temperature and then
5   heating it in a reheating furnace.

No specific limit is particularly set to the
temperature of reheating, but it is desirable that a
reheating temperature be below 1,400°C since, when it is
1,400°C or higher, the amount of scale off becomes large
10   and the product yield is lowered. It is also desirable
that a reheating temperature be 1,000°C or higher since a
reheating temperature of below 1,000°C remarkably lowers
the operation efficiency of the mill in the rolling
schedule. Further, in relation to the item (8), (9) or
15   (10) in particular, it is desirable that a reheating
temperature be 1,100°C or higher, because, when the
reheating temperature is below 1,100°C, not only
precipitates containing Ti and/or Nb coarsen without
remelting in a slab and thus their precipitation
20   strengthening capacity is lost, but also precipitates
containing Ti and/or Nb having a size and a distribution
desirable for improving burring workability do not
precipitate.

In a hot rolling process, a slab undergoes finish
25   rolling after completing rough rolling. When descaling
is applied after completing rough rolling, it is
desirable that the following condition be satisfied:

$$P \text{ (MPa)} \times L \text{ (l/cm}^2) \geqq 0.0025,$$

where P (MPa) is an impact pressure of high-pressure
30   water on a steel sheet surface, and L (l/cm^2) is a flow
rate of descaling water.

An impact pressure P of high-pressure water on a
steel sheet surface is expressed as follows (see Tetsu-
to-Hagane, 1991, Vol. 77, No. 9, p.1450):

35     $$P \text{ (MPa)} = 5.64 \times P0 \times V \times H^2,$$

where, P0 (MPa) is a pressure of liquid, V (l/min.) is a
liquid flow rate of a nozzle, and H (cm) is a distance

between a nozzle and the surface of a steel sheet.

The flow rate L ($1/cm^2$) is expressed as follows:

L ($1/cm^2$) = V/(W x v)

where, V (1/min.) is a liquid flow rate of a nozzle, W (cm) is the width where the liquid blown from a nozzle hits a steel sheet surface, and v (cm/min.) is a travelling speed of a steel sheet.

For obtaining the effects of the present invention, it is not necessary to particularly set an upper limit to the product of the impact pressure P and the flow rate L, but it is preferable that the product be 0.02 or less because, when the liquid flow rate of a nozzle is raised, troubles such as the increased wear of the nozzle occur.

It is preferable, further, that the maximum roughness height Ry of a steel sheet after finish rolling be 15 μm (we define as 15 μmRy, This is a result when the standard length l is 2.5 mm and the length of evaluation ln is 12.5 mm applied to the method described in p5 - p7 of JIS B 0601-1994.) or less. The reason for this is clear from the fact that the fatigue strength of a steel sheet as hot-rolled or as pickled correlates with the maximum roughness height Ry of the steel sheet surface, as stated in page 84 of Metal Material Fatigue Design Handbook edited by the Society of Materials Science, Japan, for example. Further, it is preferable that the finish hot rolling be done within 5 sec. after high pressure descaling, in order to prevent scales from forming again.

In addition, in order to realize an effect to lower a friction coefficient by applying a composition having a lubricating effect, it is desirable that the arithmetic average of roughness Ra of the surface of a steel sheet after finish rolling be 3.5 or less, unless the steel sheet is subjected to skin pass rolling or cold rolling after hot rolling or pickling.

Besides the above, the finish rolling may be conducted continuously by welding sheet bars together

after rough rolling or the subsequent descaling. In this case, the rough-rolled sheet bars may be welded together after being coiled temporarily, held inside a cover having a heat retention function, as occasion demands, and then uncoiled.

When a hot-rolled steel sheet is used as a final product, it is necessary that the finish rolling be done at a total reduction ratio of 25% or more in the temperature range of the Ar_3 transformation temperature + 100°C or lower during the latter half of the finish rolling. Here, the Ar_3 transformation temperature can be expressed in relation to the steel chemical components, in a simplified manner, by the following equation, for instance:

$$Ar_3 = 910 - 310 \times \%C + 25 \times \%Si - 80 \times \%Mn.$$

When the total reduction ratio in the temperature range of the Ar_3 transformation temperature + 100°C or lower is less than 25%, the rolled austenite texture does not develop sufficiently and, as a result, the effects of the present invention are not obtained, no matter how the steel sheet is cooled thereafter. For obtaining a sharper texture, it is desirable that the total reduction ratio in the temperature range of the Ar_3 transformation temperature + 100°C or lower be 35% or more.

The present invention does not particularly specify a lower limit of the temperature range when the rolling of a total reduction ratio of 25% or more is carried out. However, when the rolling is done at a temperature below the Ar_3 transformation temperature, a work-induced structure remains in ferrite having precipitated during the rolling, and, as a result, ductility is lowered and workability is deteriorated. For this reason, it is desirable that the lower limit of the temperature range when the rolling of a total reduction ratio of 25% or more is carried out be equal to or higher than the Ar_3 transformation temperature. However, if recovery or recrystallization is to be advanced to some extent during

the subsequent coiling process or a heat treatment after
the coiling process, a temperature below the Ar_3
transformation temperature is acceptable.

5   The present invention does not particularly specify
an upper limit of the total reduction ratio in the
temperature range of the Ar_3 transformation temperature +
100°C or lower. However, when the total reduction ratio
exceeds 97.5%, the rolling load becomes too high and it
becomes necessary to increase the rigidity of the mill
10   excessively, resulting in economical disadvantage. For
this reason, the total reduction ratio is, desirably,
97.5% or less.

          Here, when the friction between a hot-rolling roll
and a steel sheet is large during hot rolling in the
15   temperature range of the Ar_3 transformation temperature +
100°C or lower, crystal orientations mainly composed of
{110} develop at planes near the surfaces of a steel
sheet, causing the deterioration of a shape fixation
property. As a countermeasure, lubrication is applied,
20   as occasion demands, for reducing the friction between a
hot-rolling roll and a steel sheet.

          The present invention does not particularly specify
an upper limit of the friction coefficient between a hot-
rolling roll and a steel sheet. However, when it exceeds
25   0.2, crystal orientations mainly composed of {110}
develop conspicuously, deteriorating a shape fixation
property. For this reason, it is desirable to control
the friction coefficient between a hot-rolling roll and a
steel sheet to 0.2 or less at least at one of the passes
30   of the hot rolling in the temperature range of the Ar_3
transformation temperature + 100°C or lower. It is
preferable yet to control the friction coefficient
between a hot-rolling roll and a steel sheet to 0.15 or
less at all the passes of the hot rolling in the
35   temperature range of the Ar_3 transformation temperature +
100°C or lower. Here, the friction coefficient between a
hot-rolling roll and a steel sheet is the value

calculated from a forward slip ratio, a rolling load, a rolling torque and so on based on the rolling theory.

The present invention does not particularly specify the temperature at the final pass (FT) of a finish rolling, but it is desirable that the temperature at the final pass (FT) of a finish rolling be equal to or above the Ar_3 transformation temperature. This is because, if the rolling temperature falls below the Ar_3 transformation temperature during hot rolling, a work-induced structure remains in ferrite having precipitated before or during the rolling, and, as a result, ductility is lowered and workability is deteriorated. However, when a heat treatment for recovery or recrystallization is to be applied during or after the subsequent coiling process, the temperature at the final pass (FT) of the finish rolling is allowed to be below the Ar_3 transformation temperature.

The present invention does not particularly specify an upper limit of a finishing temperature, but, if a finishing temperature exceeds the Ar_3 transformation temperature + 100°C, it becomes substantially impossible to carry out rolling at a total reduction ratio of 25% or more in the temperature range of the Ar_3 transformation temperature + 100°C or lower. For this reason, it is desirable that the upper limit of a finishing temperature be the Ar_3 transformation temperature + 100°C or lower.

In the present invention, it is not necessary to particularly specify the microstructure of a steel sheet for the purpose of improving a shape fixation property and, thus, no specific limitation is set forth regarding the cooling process after the completion of finish rolling until the coiling at a prescribed coiling temperature. Nevertheless, a steel sheet is cooled, as occasion demands, for the purpose of securing a prescribed coiling temperature or controlling a microstructure.

The present invention does not particularly specify

an upper limit of a cooling rate, but, since thermal
strain may cause the warping of a steel sheet, it is
desirable to control the cooling rate to 300°C/sec. or
less. In addition, when a cooling rate is too high, it

5   becomes impossible to accurately control the cooling end
temperature and an over-cooling may happen as a result of
overshooting to a temperature below a prescribed coiling
temperature. For this reason, the cooling rate here is,
desirably, 150°C/sec. or less. No lower limit of the

10   cooling rate is set forth specifically, either. For
reference, the cooling rate in the case where a steel
sheet is left to cool naturally in room temperature
without any intentional cooling is 5°C/sec. or more.

In order to obtain a low yield ratio for realizing a

15   better shape fixation property than the once improved
shape fixation property in the present invention, it is
necessary that the microstructure of a steel sheet is a
compound structure containing ferrite as the phase
accounting for the largest volume percentage and

20   martensite mainly as the second phase, as described in
the item (3). To do so, a hot-rolled steel sheet has to
be retained for 1 to 20 sec. in the temperature range
from the Ar_3 transformation temperature to the Ar_1
transformation temperature (the ferrite-austenite two-

25   phase zone) in the first place after completing finish
rolling. Here, the retention of a hot-rolled steel sheet
is carried out for accelerating ferrite transformation in
the two-phase zone. If the retention time is less than 1
sec., the ferrite transformation in the two-phase zone is

30   insufficient, and a sufficient ductility is not obtained,
but, if it exceeds 20 sec., pearlite forms and the
envisaged compound structure containing ferrite as the
phase accounting for the largest volume percentage and
martensite mainly as the second phase is not obtained.

35   In addition, in order to easily accelerate the
ferrite transformation, it is desirable that the
temperature range in which a steel sheet is retained for

1 to 20 sec. be from the Ar₁ transformation temperature
to 800°C. Further, in order not to lower productivity
drastically, it is desirable that the retention time,
which has been defined earlier as from 1 to 20 sec., be 1

5   to 10 sec.

For satisfying all these conditions, it is necessary
to reach the temperature range rapidly at a cooling rate
of 20°C/sec. or more after completing finish rolling.
The upper limit of a cooling rate is not particularly

10   specified, but, in consideration of the capacity of
cooling equipment, a reasonable cooling rate is
300°C/sec. or less. In addition, when a cooling rate is
too high, it becomes impossible to accurately control the
cooling end temperature and over-cooling may happen as a

15   result of overshooting to the Ar₁ transformation
temperature or below. For this reason, the cooling rate
here is, desirably, 150°C/sec. or less.

Subsequently, a steel sheet is cooled at a cooling
rate of 20°C/sec. or more from the above temperature

20   range to a coiling temperature (CT). At a cooling rate
below 20°C/sec., pearlite or bainite forms and a
sufficient amount of martensite is not obtained and, as a
result, the envisaged microstructure containing ferrite
as the phase accounting for the largest volume percentage

25   and martensite as the second phase is not obtained. The
effects of the present invention can be enjoyed without
bothering to particularly specify an upper limit of the
cooling rate down to the coiling temperature but, for
avoiding warping caused by thermal strain, it is

30   preferable to control the cooling rate to 300°C/sec. or
less.

In order to obtain a good ductility, in addition to
improving the shape fixation property, in the present
invention, it is necessary that the microstructure of a

35   steel sheet is a compound structure containing retained
austenite by 5% to 25% in terms of volume percentage and
having the balance mainly consisting of ferrite and

bainite, as described in the item (4). To do so, a hot-
rolled steel sheet has to be retained for 1 to 20 sec. in
the temperature range from the Ar_3 transformation
temperature to the Ar_1 transformation temperature (the
5   ferrite-austenite two-phase zone) in the first place
after completing finish rolling. Here, the retention of
a hot-rolled steel sheet is carried out for accelerating
ferrite transformation in the two-phase zone. If the
retention time is less than 1 sec., the ferrite
10   transformation in the two-phase zone is insufficient and
a sufficient ductility is not obtained, but, if it
exceeds 20 sec., pearlite forms and the envisaged
microstructure containing retained austenite by 5% to 25%
in terms of volume percentage and having the balance
15   mainly consisting of ferrite and bainite is not obtained.
In addition, in order to easily accelerate the ferrite
transformation, it is desirable that the temperature
range in which a steel sheet is retained for 1 to 20 sec.
be from the Ar_1 transformation temperature to 800°C.
20   Further, in order not to lower productivity drastically,
it is desirable that the retention time, which has been
defined earlier as from 1 to 20 sec., be 1 to 10 sec.
        For satisfying all these conditions, it is necessary
to reach said temperature range rapidly at a cooling rate
25   of 20°C/sec. or more after completing finish rolling.
The upper limit of a cooling rate is not particularly
specified, but, in consideration of the capacity of
cooling equipment, a reasonable cooling rate is
300°C/sec. or less. In addition, when a cooling rate is
30   too high, it becomes impossible to accurately control the
cooling end temperature and over-cooling may happen as a
result of overshooting to the Ar_1 transformation
temperature or below. For this reason, the cooling rate
here is, desirably, 150°C/sec. or less.
35   Subsequently, a steel sheet is cooled at a cooling
rate of 20°C/sec. or more from the above temperature
range to a coiling temperature (CT). At a cooling rate

below 20°C/sec., pearlite or bainite containing carbides
forms and a sufficient amount of retained austenite is
not obtained and, as a result, the envisaged
microstructure containing retained austenite by 5% to 25%
in terms of volume percentage and having the balance
mainly consisting of ferrite and bainite is not obtained.
The effects of the present invention can be enjoyed
without bothering to particularly specify an upper limit
of the cooling rate down to the coiling temperature but,
for avoiding warping caused by thermal strain, it is
preferable to control the cooling rate to 300°C/sec. or
less.

In order to obtain a good burring workability, in
addition to improving a shape fixation property, in the
present invention, it is necessary that the
microstructure is a compound structure containing bainite
or ferrite and bainite as the phase accounting for the
largest volume percentage, as described in the item (5).
To do so, the present invention does not particularly
specify the process conditions after the completion of
finish rolling until coiling at a prescribed coiling
temperature, except for the cooling rate applied during
the process. However, in case where a steel sheet is
required to have both a good burring workability and a
high ductility without sacrificing the burring
workability too much, it is acceptable to retain a hot-
rolled steel sheet for 1 to 20 sec. in the temperature
range from the Ar_3 transformation temperature to the Ar_1
transformation temperature (the ferrite-austenite two-
phase zone).

Here, the retention of a hot-rolled steel sheet is
carried out for accelerating ferrite transformation in
the two-phase zone. If the retention time is less than 1
sec., the ferrite transformation in the two-phase zone is
insufficient, and a sufficient ductility is not obtained,
but, if it exceeds 20 sec., pearlite forms and the
envisaged microstructure of a compound structure

containing bainite or ferrite and bainite as the phase
accounting for the largest volume percentage is not
obtained. In addition, in order to easily accelerate the
ferrite transformation, it is desirable that the
5   temperature range in which a steel sheet is retained for
1 to 20 sec. be from the Ar_1 transformation temperature
to 800°C. Further, in order not to lower productivity
drastically, it is desirable that the retention time,
which has been defined earlier as from 1 to 20 sec., be 1
10   to 10 sec.

For satisfying all these conditions, it is necessary
to reach said temperature range rapidly at a cooling rate
of 20°C/sec. or more after completing the finish rolling.
The upper limit of a cooling rate is not particularly
15   specified, but, in consideration of the capacity of
cooling equipment, a reasonable cooling rate is
300°C/sec. or less. In addition, when a cooling rate is
too high, it becomes impossible to accurately control the
cooling end temperature and over-cooling may happen as a
20   result of overshooting to the Ar_1 transformation
temperature or below, losing the effect of improving
ductility. For this reason, the cooling rate here is,
desirably, 150°C/sec. or less.

Subsequently, a steel sheet is cooled at a cooling
25   rate of 20°C/sec. or more from the above temperature
range to a coiling temperature (CT). At a cooling rate
below 20°C/sec., pearlite or bainite containing carbides
forms and the envisaged microstructure of a compound
structure containing bainite or ferrite and bainite as
30   the phase accounting for the largest volume percentage is
not obtained. The effects of the present invention can
be enjoyed without bothering to particularly specify an
upper limit of the cooling rate down to the coiling
temperature but, for avoiding warping caused by thermal
35   strain, it is preferable to control the cooling rate to
300°C/sec. or less.

In addition, in order to obtain a steel sheet

according to any one of the items (8) − (10) in the
present invention, the present invention does not
particularly specify the process conditions after the
completion of finish rolling until coiling at a

5   prescribed coiling temperature (CT). However, in case
where a steel sheet is required to have both a good
burring workability and a high ductility without
sacrificing the burring workability too much, it is
acceptable to retain a hot-rolled steel sheet for 1 to 20

10 sec. in the temperature range from the Ar_3 transformation
temperature to the Ar_1 transformation temperature (the
ferrite-austenite two-phase zone). Here, the retention
of a hot-rolled steel sheet is carried out for
accelerating ferrite transformation in the two-phase

15 zone. If the retention time is less than 1 sec., the
ferrite transformation in the two-phase zone is
insufficient, and a sufficient ductility is not obtained,
but, if it exceeds 20 sec., the size of precipitates
containing Ti and/or Nb becomes coarse and there arises a

20 probability that they do not contribute to the increase
of steel strength caused by precipitation strengthening.
In addition, in order to easily accelerate the ferrite
transformation, it is desirable that the temperature
range in which a steel sheet is retained for 1 to 20 sec.

25 be from the Ar_1 transformation temperature to 860°C.
Further, in order not to lower productivity drastically,
it is desirable that the retention time, which has been
defined earlier as from 1 to 20 sec., be 1 to 10 sec.
For satisfying all these conditions, it is necessary

30 to reach the temperature range rapidly at a cooling rate
of 20°C/sec. or more after completing finish rolling.
The upper limit of a cooling rate is not particularly
specified, but, in consideration of the capacity of
cooling equipment, a reasonable cooling rate is

35 300°C/sec. or less. In addition, when a cooling rate is
too high, it becomes impossible to accurately control the
cooling end temperature and over-cooling may happen as a

result of overshooting to the Ar_1 transformation temperature or below, losing the effect of improving ductility. For this reason, the cooling rate here is, desirably, 150°C/sec. or less.

Subsequently, a steel sheet is cooled from the above temperature range to a prescribed coiling temperature (CT), but it is not necessary to particularly specify a cooling rate for obtaining the effects of the present invention. However, when a cooling rate is too low, the size of precipitates containing Ti and/or Nb becomes coarse and there arises a probability that they do not contribute to the enhancement of steel strength caused by precipitation strengthening. For this reason, it is desirable that the lower limit of the cooling rate be 20°C/sec. or more. The effects of the present invention can be enjoyed without bothering to particularly specify an upper limit of the cooling rate down to the coiling temperature but, for avoiding warping caused by thermal strain, it is preferable to control the cooling rate to 300°C/sec. or less.

In the present invention, it is not necessary to particularly specify the microstructure of a steel sheet for the purpose of improving a shape fixation property and, thus, the present invention does not particularly specify an upper limit of a coiling temperature. However, in order to carry over the texture of austenite obtained by a finish rolling at a total reduction ratio of 25% or more in the temperature range of the Ar_3 transformation temperature + 100°C or lower, it is desirable to coil a steel sheet at the coiling temperature T0 shown below or lower. Note that it is unnecessary to set the temperature T0 equal to or below the room temperature. The temperature T0 is a temperature defined thermodynamically as a temperature at which austenite and ferrite having the same chemical components as the austenite have the same free energy. It can be calculated in a simplified manner by the

following equation, taking the influences of components
other than C into consideration:

$$T0 = -650.4 \times \%C + B,$$

where, B is determined as follows:

$$B = -50.6 \times Mneq + 894.3,$$

where, Mneq is determined from the mass percentages of
the component elements as shown below:

$$Mneq = \%Mn + 0.24 \times \%Ni + 0.13 \times \%Si + 0.38 \times \%Mo +$$

$$0.55 \times \%Cr + 0.16 \times \%Cu - 0.50 \times \%Al - 0.45 \times \%Co + 0.90$$

$$\times \%V.$$

Note that the influences on T0 of the mass
percentages of the other components specified in the
present invention than those included in the above
equation are not significant, and are negligible here.

Since it is not necessary to particularly specify
the microstructure of a steel sheet for the purpose of
improving a shape fixation property, it is not necessary
to particularly specify a lower limit of a coiling
temperature. However, for avoiding poor appearance
caused by rust when a coil is kept wet with water for a
long period of time, it is desirable that a coiling
temperature be 50°C or above.

In order to obtain a low yield ratio, in addition to
improving a shape fixation property, in the present
invention, it is necessary that the microstructure is a
compound structure containing ferrite as the phase
accounting for the largest volume percentage and
martensite mainly as the second phase, as described in
the item (3). To do so, it is necessary that a coiling
temperature be 350°C or less. The reason is because,
when a coiling temperature exceeds 350°C, bainite forms
and a sufficient amount of martensite is not obtained
and, as a result, the envisaged microstructure containing
ferrite as the phase accounting for the largest volume
percentage and martensite as the second phase is not
obtained. It is not necessary to particularly set forth
a lower limit of a coiling temperature but, for avoiding

poor appearance caused by rust when a coil is kept wet with water for a long period of time, it is desirable that a coiling temperature be 50°C or above.

In order to obtain a good ductility, in addition to improving a shape fixation property, in the present invention, it is necessary that the microstructure is a compound structure containing retained austenite by 5 to 25% in terms of volume percentage and having the balance mainly consisting of ferrite and bainite, as described in the item (4). To do so, a coiling temperature must be restricted to below 450°C. This is because, when a coiling temperature is 450°C or higher, bainite containing carbides forms and a sufficient amount of retained austenite is not obtained and, as a result, the envisaged microstructure containing retained austenite by 5 to 25% in terms of volume percentage and having the balance mainly consisting of ferrite and bainite is not obtained. When a coiling temperature is 350°C or lower, on the other hand, a great amount of martensite forms and a sufficient amount of retained austenite is not obtained and, as a result, the envisaged microstructure containing retained austenite by 5 to 25% in terms of volume percentage and having the balance mainly consisting of ferrite and bainite is not obtained. For this reason, the coiling temperature is limited to over 350°C.

Further, while the present invention does not particularly specify a cooling rate to be applied after coiling, when Cu is added by 1% or more, Cu precipitates after coiling and not only workability is deteriorated but also solute Cu effective for improving fatigue properties may be lost. For this reason, it is desirable that the cooling rate after coiling be 30°C/sec. or more up to the temperature of 200°C.

In order to obtain a good burring workability, in addition to improving the shape fixation property, in the present invention, it is necessary that the microstructure is a compound structure containing bainite

or of ferrite and bainite as the phase accounting for the largest volume percentage, as described in the item (5). To do so, a coiling temperature has to be restricted to 450°C or more. This is because, when a coiling

5   temperature is below 450°C, retained austenite or martensite considered detrimental to burring workability may form in a great amount and, as a consequence, the envisaged microstructure of a compound structure containing bainite or ferrite and bainite as the phase

10   accounting for the largest volume percentage is not obtained. Further, while the present invention does not particularly specify a cooling rate to be applied after coiling, when Cu is added by 1.2% or more, Cu precipitates after coiling and not only workability is

15   deteriorated but also solute Cu effective for improving fatigue properties may be lost. For this reason, it is desirable that the cooling rate after coiling be 30°C/sec. or more up to the temperature of 200°C.

     The present invention does not particularly specify

20   a coiling temperature (CT) for the purpose of obtaining a steel sheet according to any one of the items (8) ~ (10). However, in order to carry over the texture of austenite obtained by a finish rolling at a total reduction ratio of 25% or more in the temperature range of the Ar_3

25   transformation temperature + 100°C or lower, it is desirable to coil a steel sheet at the coiling temperature T0 shown below or lower. The temperature T0 is a temperature defined thermodynamically as a temperature at which austenite and ferrite having the

30   same chemical components as the austenite have the same free energy. It can be calculated in a simplified manner by the following equation, taking the influences of components other than C into consideration:

       T0 = -650.4 x %C + B,

35   where, B is determined as follows:

       B = -50.6 x Mneq + 894.3,

where, Mneq is determined from the mass percentages of

the component elements as shown below:

Mneq = %Mn + 0.24 x %Ni + 0.13 x %Si + 0.38 x %Mo + 0.55 x %Cr + 0.16 x %Cu - 0.50 x %Al - 0.45 x %Co + 0.90 x %V.

5   Note that the influences on T0 of the mass percentages of the other components specified in the present invention than those included in the above equation are not significant, and are negligible here.

       As for the lower limit of a coiling temperature
10   (CT), on the other hand, it is desirable to coil a steel sheet at a temperature above 350°C, because, at 350°C or below, the precipitates containing Ti and/or Nb do not form in a sufficient amount and solute C remains in the steel, probably deteriorating workability. Further,
15   while the present invention does not particularly specify a cooling rate to be applied after coiling, when Cu is added by 1% or more and if the coiling temperature (CT) exceeds 450°C, Cu precipitates after coiling, and not only workability is deteriorated but also solute Cu
20   effective for improving fatigue properties may be lost. For this reason, when a coiling temperature (CT) exceeds 450°C, it is desirable that the cooling rate after coiling be 30°C/sec. or more up to the temperature of 200°C.

25   After completing a hot rolling process, a steel sheet may undergo pickling, as occasion demands, and then skin pass rolling at a reduction ratio of 10% or less or cold rolling at a reduction ratio up to 40% or so, either in-line or off-line. However, in this case, in order to
30   obtain the effect to reduce a friction coefficient by applying a composition having a lubricating effect, it is necessary to control the reduction ratio of the skin pass rolling so that the arithmetic average of roughness Ra of at least one of the surfaces of a steel sheet becomes 1
35   to 3.5 μm after the skin pass rolling.

       Next, in the case where a cold-rolled steel sheet is used as a final product, the present invention does not

particularly specify the conditions of finish hot
rolling. However, for obtaining a better shape fixation
property, it is desirable to apply a total reduction
ratio of 25% or more in the temperature range of the Ar_3
5   transformation temperature + 100°C or lower. Further,
while it is acceptable that the temperature at the final
pass (FT) of a finish rolling be below the Ar_3
transformation temperature, in such a case, since an
intensively work-induced structure remains in ferrite
10   having precipitated before or during the rolling, it is
desirable that the work-induced structure be recovered
and recrystallized by a subsequent coiling process or
heat treatment.

The total reduction ratio at a cold rolling
15   subsequent to pickling is set at less than 80%. This is
because, when the total reduction ratio at a cold rolling
is 80% or more, the ratio of integrated X-ray diffraction
strength in {111} and {554} crystal planes parallel to
the plane of a steel sheet, which constitute a
20   recrystallization texture usually obtained by cold
rolling, tends to be large. A preferable total reduction
ratio at a cold rolling is 70% or less. The effects of
the present invention can be enjoyed without particularly
specifying a lower limit of a cold reduction ratio, but,
25   for controlling the X-ray diffraction strengths in the
crystal orientation components within appropriate ranges,
it is desirable to set the lower limit of a cold
reduction ratio at 3% or more.

The discussion here is based on the assumption that
30   the heat treatment of a cold-rolled steel sheet is
carried out in a continuous annealing process.

In the first place, a steel sheet is heat-treated
for 5 to 150 sec. in the temperature range of the Ac_3
transformation temperature + 100°C or lower. If the
35   upper limit of a heat treatment temperature exceeds the
Ac_3 transformation temperature + 100°C, ferrite having
formed through recrystallization transforms into

austenite, the texture formed by the growth of austenite
grains is randomized, and the texture of ferrite finally
obtained is also randomized. For this reason, the upper
limit of a heat treatment temperature is determined to be

5   the Ac_3 transformation temperature + 100°C or lower. The
Ac_1 and Ac_3 transformation temperatures mentioned here
can be expressed in relation to steel chemical components
using, for example, the expressions according to p. 273
of the Japanese translation of The Physical Metallurgy of

10   Steels by W. C. Leslie (published from Maruzen in 1985,
translated by Hiroshi Kumai and Tatsuhiko Noda). It is
acceptable if the lower limit of a heat treatment
temperature is equal to or above the recovery
temperature, because it is not necessary to particularly

15   specify the microstructure of a steel sheet for the
purpose of improving a shape fixation property. When a
heat treatment temperature is below the recovery
temperature, however, a work-induced structure is
retained and formability is significantly deteriorated.

20   For this reason, the lower limit of a heat treatment
temperature is determined to be equal to or above the
recovery temperature. For obtaining yet better
ductility, it is desirable that a heat treatment
temperature be equal to or above the recrystallization

25   temperature of a steel.
       Further, with regard to a retention time in the
above temperature range, if the retention time is shorter
than 5 sec., it is insufficient for having cementite
completely dissolve again, but, if the retention time

30   exceeds 150 sec., the effect of the heat treatment is
saturated and, what is more, productivity is lowered.
For this reason, the retention time is determined to be
in the range from 5 to 150 sec.
       Further, in the case of a steel sheet according to

35   any one of the items (8) ~ (10), in particular, the
retention time is determined to be in the range from 5 to
150 sec. too, because, if the retention time in the

temperature range is shorter than 5 sec., it is insufficient for carbonitrides of Ti and Nb to completely dissolve again, but, if the retention time exceeds 150 sec., the effect of the heat treatment is saturated and,
5   what is more, productivity is lowered.

The present invention does not particularly specify the conditions of cooling after a heat treatment. However, for the purpose of controlling a microstructure, a mere cooling process or the combination of a retention
10   process at a certain temperature with a cooling process may be employed as occasion demands, as it is mentioned later.

In order to obtain a low yield ratio, in addition to improving a shape fixation property, in the present
15   invention, it is necessary that the microstructure is a compound structure containing ferrite as the phase accounting for the largest volume percentage and martensite mainly as the second phase, as described in the item (3). To do so, a hot-rolled steel sheet is
20   determined to be retained for 5 to 150 sec. in the temperature range from the Ac_1 transformation temperature to the Ac_3 transformation temperature + 100°C, as described earlier. In this case, if cementite has precipitated in an as hot-rolled state and if the
25   temperature is too low even it is within said temperature range, it takes too long a time for the cementite to dissolve again. When the temperature is too high, on the other hand, the volume percentage of austenite becomes too large and the concentration of C in the austenite
30   becomes too low, and, as a consequence, the temperature history of the steel is likely to pass through the transformation nose of bainite or pearlite containing much carbide. For this reason, it is desirable to heat the steel sheet to a temperature from 780 to 850°C.

35   If a cooling rate after the retention is below 20°C/sec., the temperature history of the steel is likely to pass through the transformation nose of bainite or

pearlite containing much carbide, and, for this reason,
the cooling rate is determined to be 20°C/sec. or more.
If a cooling end temperature is above 350°C, the
envisaged microstructure containing ferrite as the phase

5   accounting for the largest volume percentage and
martensite as the second phase is not obtained. For this
reason, the cooling must be continued down to a
temperature of 350°C or lower. The present invention
does not particularly specify a lower limit of a

10 temperature at the end of a cooling process, but, if
water cooling or mist cooling is applied and a coil is
kept wet with water for a long period of time, for
avoiding poor appearance caused by rust, it is desirable
that a temperature at the end of a cooling process be

15 50°C or above.
        In order to obtain a good ductility, in addition to
improving a shape fixation property, in the present
invention, it is necessary that the microstructure is a
compound structure containing retained austenite by 5 to

20 25% in terms of volume percentage and having the balance
mainly consisting of ferrite and bainite, as described in
the item (4). To do so, a steel sheet is determined to
be heat-treated for 5 to 150 sec. in a temperature range
from the Ac_1 transformation temperature to the Ac_3

25 transformation temperature + 100°C, as described earlier.
In this case, if cementite has precipitated in an as hot-
rolled state and if the temperature is too low even
within the temperature range, it takes too long a time
for the cementite to dissolve again. When the

30 temperature is too high, on the other hand, the volume
percentage of austenite becomes too large and the
concentration of C in the austenite becomes too low, and,
as a consequence, the temperature history of the steel is
likely to pass through the transformation nose of bainite

35 or pearlite containing much carbide. For this reason, it
is desirable to heat the steel sheet to a temperature
from 780 to 850°C. If a cooling rate after the retention

is below 20°C/sec., the temperature history of the steel is likely to pass through the transformation nose of bainite or pearlite containing much carbide, and, for this reason, the cooling rate is determined to be
5   20°C/sec. or more.

Next, with respect to a process to accelerate bainite transformation and stabilize a required amount of retained austenite, if a temperature at the end of cooling is 450°C or higher, the retained austenite is
10   decomposed into bainite or pearlite containing much carbide, and the envisaged microstructure containing retained austenite by 5 to 25% in terms of volume percentage and having the balance mainly consisting of ferrite and bainite is not obtained. If a cooling end
15   temperature is below 350°C, martensite may form in a great amount and a sufficient amount of retained austenite cannot be secured and, as a result, the envisaged microstructure containing retained austenite by 5 to 25% in terms of volume percentage and the balance
20   mainly consisting of ferrite and bainite is not obtained. For this reason, the cooling must be carried out to the temperature range of above 350°C.

Further, with respect to the retention time in the above temperature range, if the retention time is shorter
25   than 5 sec., bainite transformation for stabilizing retained austenite is insufficient and, as a consequence, the unstable retained austenite may transform into martensite at the end of the subsequent cooling stage, and, as a result, the envisaged microstructure containing
30   retained austenite by 5 to 25% in terms of volume percentage and having the balance mainly consisting of ferrite and bainite is not obtained. If the retention time exceeds 600 sec., on the other hand, bainite transformation overshoots and a required amount of stable
35   retained austenite is not formed, and, as a result, the envisaged microstructure containing retained austenite by 5 to 25% in terms of volume percentage and having the

balance mainly consisting of ferrite and bainite is not obtained. For this reason, the retention time in the temperature range is determined to be from 5 to 600 sec.

Finally, if a cooling rate up to the end of cooling is below 5°C/sec., there is a probability that the bainite transformation overshoots during the cooling and a required amount of stable retained austenite is not formed, and, as a consequence, the envisaged microstructure containing retained austenite by 5 to 25% in terms of volume percentage and having the balance mainly consisting of ferrite and bainite may not be obtained. Therefore, the cooling rate is determined to be 5°C/sec. or more. In addition, if a temperature at the end of cooling exceeds 200°C, an aging property may be deteriorated and, therefore, a cooling end temperature is determined to be 200°C or lower. The present invention does not particularly specify the lower limit of a temperature at the end of cooling, but, if water cooling or mist cooling is applied and a coil is kept wet with water for a long period of time, for avoiding poor appearance caused by rust, it is desirable that a cooling end temperature be 50°C or above.

Additionally, in order to obtain a good burring workability, in addition to improving a shape fixation property, in the present invention, it is necessary that the microstructure of a compound structure containing bainite or ferrite and bainite as the phase accounting for the largest volume percentage is obtained, as described in the item (5). To do so, the lower limit of the heat treatment temperature is determined to be the Ac_1 transformation temperature or higher. If the lower limit of the heat treatment temperature is below the Ac_1 transformation temperature, the envisaged compound structure containing bainite or of ferrite and bainite as the phase accounting for the largest volume percentage is not obtained. When it is intended to obtain both a good burring workability and a high ductility without

sacrificing the burring workability too much, the heat
treatment temperature is determined to be in the range
from the Ac_1 transformation temperature to the Ac_3
transformation temperature (the ferrite-austenite two-
phase zone) for the purpose of increasing the volume
percentage of ferrite. Further, in order to obtain a yet
better burring workability, it is desirable that the heat
treatment temperature is in the range from the Ac_3
transformation temperature to the Ac_3 transformation
temperature + 100°C for increasing the volume percentage
of bainite.

The present invention does not particularly specify
the conditions of a cooling process, but, when said heat
treatment temperature is in the range from Ac_1
transformation temperature to Ac_3 transformation
temperature, it is desirable to cool a steel sheet at a
cooling rate of 20°C/sec. or more to the temperature
range from over 350°C to not more than the temperature TO
specified herein earlier. This is because, if a cooling
rate is below 20°C/sec., the temperature history of the
steel is likely to pass through the transformation nose
of bainite or pearlite containing much carbide. Further,
when a cooling end temperature is 350°C or lower,
martensite, which is considered detrimental to burring
properties, may form in a great amount and, as a result,
the envisaged compound structure containing bainite or
ferrite and bainite as the phase accounting for the
largest volume percentage is not obtained. For this
reason, it is desirable that a cooling end temperature be
above 350°C. In addition, in order to carry over the
texture obtained up to the previous process, it is
desirable that the cooling end temperature be TO or
lower.

Finally, if a cooling rate down to the temperature
at the end of a cooling process is 20°C/sec. or more,
there is a probability that martensite, which is
considered detrimental to burring properties, forms in a

great amount during the cooling and, as a result, the
envisaged compound structure containing bainite or
ferrite and bainite as the phase accounting for the
largest volume percentage may not be obtained.

5   Consequently, it is desirable that the cooling rate be
below 20°C/sec. Besides, if a temperature at the end of
a cooling process exceeds 200°C, aging properties may be
deteriorated. Therefore, it is desirable that the
temperature at the end of the cooling process be 200°C or

10   lower. For avoiding poor appearance caused by rust, if
water cooling or mist cooling is applied and a coil is
kept wet with water for a long period of time, it is
desirable that the lower limit of a temperature at the
end of a cooling process be 50°C or above.

15   On the other hand, in the case where said heat
treatment temperature is within the range from the Ac_3
transformation temperature to the Ac_3 transformation
temperature + 100°C, it is desirable to cool a steel
sheet at a cooling rate of 20°C/sec. or more to a

20   temperature of 200°C or below. This is because, if a
cooling rate is below 20°C/sec., the temperature history
of the steel is likely to pass through the transformation
nose of bainite or pearlite containing much carbide. In
addition, if a temperature at the end of a cooling

25   process exceeds 200°C, aging properties may be
deteriorated. Therefore, it is desirable that a
temperature at the end of a cooling process be 200°C or
lower. For avoiding poor appearance caused by rust, if
water cooling or mist cooling is applied and a coil is

30   kept wet with water for a long period of time, it is
desirable that the lower limit of a temperature at the
end of a cooling process be 50°C or above.

         In additional, for the purpose of obtaining a steel
sheet according to any one of the items (8) ~ (10) in the

35   present invention, it is not necessary to particularly
specify the conditions of cooling after the heat
treatment. However, it is desirable that a steel sheet

is cooled at a cooling rate of 20°C/sec. or more to a
temperature range from over 350°C to the temperature T0
specified herein earlier. This is because, if a cooling
rate is below 20°C/sec., it is concerned that the size of
5   precipitates containing Ti and/or Nb becomes coarse and
they do not contribute to the increase of strength
through precipitation strengthening. In addition, if a
cooling end temperature is 350°C or below, there is a
probability that the precipitates containing Ti and/or Nb
10   do not form in a sufficient amount, and solute C remains
in steel, deteriorating workability. For this reason, it
is desirable that a cooling end temperature be above
350°C. Further, if a temperature at the end of a cooling
process is over 200°C, aging properties may be
15   deteriorated and, for this reason, it is desirable that a
temperature at the end of a cooling process be 200°C or
lower. If water cooling or mist cooling is applied and a
coil is kept wet with water for a long period of time,
for avoiding poor appearance caused by rust, it is
20   desirable that the lower limit of a temperature at the
end of a cooling process be 50°C or above.

After the above-mentioned processes, a skin pass
rolling is applied as occasion demands. Note that, in
this case, in order to obtain the effect to lower a
25   friction coefficient by applying a composition having a
lubricating effect, the reduction ratio of a skin pass
rolling has to be so controlled that the arithmetic
average of roughness Ra of at least one of the surfaces
of a steel sheet is 1 to 3.5 μm after the rolling.

30   In order to apply zinc plating to a hot-rolled steel
sheet after pickling or a cold-rolled steel sheet after
completing the above heat treatment for
recrystallization, the steel sheet has to be dipped in a
zinc plating bath. It may be subjected to an alloying
35   process as occasion demands.

Finally, in order to secure a good drawability, a
composition having a lubricating effect is applied to a

steel sheet after completing the above-mentioned
production processes. The method of the application is
not limited specifically as far as a desired coating
thickness is obtained. Electrostatic coating or a method
using a roll coater is commonly employed.

Example 1
     A steel sheet according to any one of the items (1)
to (5) is explained hereafter in more detail.
     Steels A to L having the chemical components listed
in Table 1 were melted and refined in a converter, cast
continuously into slabs, reheated and then rolled through
rough rolling and finish rolling into steel sheets 1.2 to
5.5 mm in thickness, and then coiled. Note that the
chemical components in the table are expressed in terms
of mass percent.
     Then, Table 2 shows the details of the production
conditions. In the table, "SRT" means the slab reheating
temperature, "FT" the finish rolling temperature at the
final pass, and "reduction ratio" the total reduction
ratio in the temperature range of the Ar_3 transformation
temperature + 100°C or lower. Note that, in the case
where a steel sheet is cold-rolled after being hot-
rolled, the restriction is not necessary to be applied
and, therefore, each relevant space of "reduction ratio"
is filled with a horizontal bar, meaning "not
applicable." Further, "lubrication" indicates if or not
lubrication is applied in the temperature range of the
Ar_3 transformation temperature + 100°C or lower. In the
column of "coiling", O means that a coiling temperature
(CT) is T0 or lower, and × that a coiling temperature is
above T0. Note that, since it is not necessary to
restrict the coiling temperature as one of the production
conditions in the case of a cold-rolled steel sheet, each
relevant space is filled with a horizontal bar, meaning
"not applicable." Some of the steel sheets underwent

pickling, cold rolling and annealing after hot rolling. The thickness of the cold-rolled steel sheets ranged from 0.7 to 2.3 mm.

5   Also in the table, "cold reduction ratio" means a total cold reduction ratio, and "time" the time of annealing. In the column of "annealing", O means that the annealing temperature is within the range from the recovery temperature to the Ar_3 transformation temperature + 100°C, and x that it is outside the range.

10   Steel L underwent a descaling under the condition of an impact pressure of 2.7 MPa and a flow rate of 0.001 l/cm² after rough rolling. Further, among the steels mentioned above, steels G and F-5 underwent zinc plating. Further, after completing the above production processes, a

15   composition having a lubricating effect was applied using an electrostatic coating apparatus or a roll coater.

    A hot-rolled steel sheet thus prepared was subjected to a tensile test by forming a specimen into a No. 5 test piece according to JIS Z 2201 and in accordance with the

20   test method specified in JIS Z 2241. The yield strength (σY), tensile strength (σB) and breaking elongation (El) are shown in Tables 2-1 and 2-2.

    Then, a test piece 30 mm in diameter were cut out from a position of 1/4 or 3/4 of the width of a steel

25   sheet, the surfaces were ground up to the three-triangle grade finish (the second finest finish) and, subsequently, strain was removed by chemical polishing or electrolytic polishing. A test piece thus prepared was subjected to X-ray diffraction strength measurement in

30   accordance with the method described in pages 274 to 296 of the Japanese translation of Elements of X-ray Diffraction by B. D. Cullity (published in 1986 from AGNE Gijutsu Center, translated by Gentaro Matsumura).

    Here, the average ratio of the X-ray strength in the

35   orientation component group of {100}<011> to {223}<110> to random X-ray diffraction strength was obtained by

obtaining the X-ray diffraction strengths in the
principal orientation components included in the
orientation component group, namely {100}<011>,
{116}<110>, {114}<110>, {113}<110>, {112}<110>,
5   {335}<110> and {223}<110>, from the three-dimensional
texture calculated by, either the vector method based on
the pole figure of {110} or the series expansion method
using two or more (desirably, three or more) pole figures
out of the pole figures of {110}, {100}, {211} and {310}.
10   For example, as the ratio of the X-ray strength in
the above crystal orientation components to random X-ray
diffraction strength calculated by the latter method, the
strengths of (001)[1-10], (116)[1-10], (114)[1-10],
(113)[1-10], (112)[1-10], (335)[1-10] and (223)[1-10] at
15   a $\phi2 = 45°$ cross section in a three-dimensional texture
can be used without modification. Note that the average
ratio of the X-ray strength in the orientation component
group of {100}<011> to {223}<110> to random X-ray
diffraction strength is the arithmetic average ratio in
20   all the above orientation components.
           When it is impossible to obtain the strengths in all
these orientation components, the arithmetic average of
the strengths in the orientation components of
{100}<011>, {116}<110>, {114}<110>, {112}<110> and
25   {223}<110> may be used as a substitute.
           In addition to the above, the average ratio of the
X-ray strength in three orientation components of
{554}<225>, {111}<112> and {111}<110> to random X-ray
diffraction strength can be calculated from the three-
30   dimensional texture obtained in the same manner as above.
           In Table 2, "strength 1" under "ratios of X-ray
strength to random X-ray diffraction strength" means the
average ratio of the X-ray strength in the orientation
component group of {100}<011> to {223}<110> to random X-
35   ray diffraction strength, and "strength 2" the average
ratio of the X-ray strength in the above three
orientation components of {554}<225>, {111}<112> and

{111}<110> to random X-ray diffraction strength.

Then, for the purpose of examining the shape
fixation property of a steel sheet, a test piece 50 mm in
width and 270 mm in length was cut out from a position of
1/4 or 3/4 of the width of the steel sheet so that the
length was in the rolling direction, and it was subjected
to a hat bending test using a punch 78 mm in width having
shoulders 5 mm in radius, and a die having shoulders 5 mm
in radius. The shape of the test piece having undergone
the bending test was measured along the width centerline
using a three-dimensional shape measuring apparatus. A
shape fixation property was evaluated using the following
indicators: dimensional accuracy evaluated by the value
obtained by subtracting the width of the punch from the
distance between points ⑤ as shown in Fig. 1; the amount
of spring back defined by the average of the two values
at the left and right portions, obtained by subtracting
90° from the angle between the straight line passing
through points ① and ② and the straight line passing
through points ③ and ④; and the amount of wall warping
defined by the average of the inverse numbers of the
curvature between points ③ and ⑤ at the left and right
portions.

It has to be noted here that the amounts of spring
back and wall warping vary depending on a blank holding
force (BHF). The tendency of the effects of the present
invention does not change even under various BHF
conditions, but, in consideration of the fact that too
high BHF cannot be imposed when an actual part is pressed
in a production site, this time, the hat bending test is
applied to various steel sheets under the BHF of 29 kN.
Based on the dimensional accuracy and wall warping amount
obtained by the bending test, a shape fixation property
can be finally judged in terms of the dimensional
accuracy (Δd). Since, as it is well known, dimensional
accuracy lowers as the strength of a steel sheet

increases, the value Δd/σB shown in Table 2 is used as an indicator of the shape fixation property.

An arithmetic average of roughness Ra was measured using a non-contact laser type measuring apparatus and in
5   accordance with the method specified in JIS B 0601-1994.

A friction coefficient was defined as the ratio (f/F) of a drawing force (f) to a pressing force (F) in the following test procedures: as seen in Fig. 2, a steel sheet to be evaluated was placed between two flat plates
10   having a Vickers hardness of Hv600 or more at the surfaces; a force (F) perpendicular to the surfaces of the subject steel sheet was imposed so that the contact stress was 1.5 to 2 kgf/mm^2; and the force (f) required for pulling out the subject steel sheet from between the
15   flat plates was measured.

In the last place, an index of drawability of a steel sheet was defined as the quotient (D/d) obtained by dividing the maximum diameter (D) in which drawing had been successful by the diameter (d) of a cylindrical
20   punch when a steel sheet was formed into a disk-shape and subjected to drawing work using the cylindrical punch. In this test, steel sheets were formed into various disk-shapes 300 to 400 mm in diameter, and a cylindrical punch 175 mm in diameter having a shoulder 10 mm in radius
25   around the bottom face and a die having a shoulder 15 mm in radius were used in the evaluation of drawability. With regard to a blank holding force, 5 kN was imposed in the case of steels A to D, 100 kN in the case of steels E, F-1 to F-10, G and I to L, and 150 kN in the case of
30   steel H.

It was understood that all the steel sheets having the friction coefficient within the range of the present invention showed a higher drawability index (D/d) than a steel sheet having the friction coefficient above the
35   range of the present invention and the drawability index of any of the former steel sheets was 1.91 or more.

The examples according to the present invention are

11 steels, namely steels A, E, F-1, F-2, F-7, G, H, I, J,
K and L. In these examples, obtained are the high-
strength thin steel sheets drawable and excellent in a
shape fixation property: characterized in that, the steel
sheets contain prescribed amounts of components, at least
on a plane at the center of the thickness of any of the
steel sheets, the average ratio of the X-ray strength in
the orientation component group of {100}<011> to
{223}<110> to random X-ray diffraction strength is 3 or
more and the average ratio of the X-ray strength in three
orientation components of {554}<225>, {111}<112> and
{111}<110> to random X-ray diffraction strength is 3.5 or
less, the arithmetic average of the roughness Ra of at
least one of the surfaces is 1 to 3.5 μm, and the
surfaces of the steel sheet is covered with a composition
having a lubricating effect; and further characterized in
that at least one of the friction coefficients in the
rolling direction and in the direction perpendicular to
the rolling direction at 0 to 200°C is 0.05 to 0.2. As a
consequence, in the evaluations by the methods according
to the present invention, the indices of the shape
fixation property of these steels were superior to those
of conventional steels.

All the steels in the tables other than those
mentioned above were outside the ranges of the present
invention for the following reasons.

In steel B, the content of C was outside the range
specified in claim 6 of the present invention and, as a
consequence, a sufficient strength (σB) was not
obtained. In steel C, the content of P was outside the
range specified in claim 6 of the present invention and,
as a consequence, good fatigue properties were not
obtained. In steel D, the content of S was outside the
range specified in claim 6 of the present invention and,
as a consequence, a sufficient elongation (El) was not
obtained. In steel F-3, since a composition having a

lubricating effect was not applied, the envisaged
friction coefficient specified in claim 2 was not
obtained and, as a consequence, a sufficient drawability
(D/d) was not obtained.

5   In steel F-4, since the arithmetic average of
roughness Ra was outside the range specified in claim 1
of the present invention, the envisaged friction
coefficient specified in claim 2 was not obtained and, as
a consequence, a sufficient drawability (D/d) was not

10   obtained. In steel F-5, since the total reduction ratio
in the temperature range of the Ar_3 transformation
temperature + 100°C or lower was outside the range
specified in claim 17 of the present invention, the
envisaged texture specified in claim 1 was not obtained

15   and, as a consequence, a sufficient shape fixation
property ($\Delta d/\sigma B$) was not obtained.

             In steel F-6, since the finish-rolling termination
temperature (FT) was outside the range specified in claim
17 of the present invention and the coiling temperature

20   was also outside the range specified in the description
of the present invention, the envisaged texture specified
in claim 1 was not obtained and, as a consequence, a
sufficient shape fixation property ($\Delta d/\sigma B$) was not
obtained. In steel F-8, since the cold reduction ratio

25   was outside the range specified in claim 24 of the
present invention, the envisaged texture specified in
claim 1 was not obtained and, as a consequence, a
sufficient shape fixation property ($\Delta d/\sigma B$) was not
obtained. In steel F-9, since the annealing temperature

30   was outside the range specified in claim 24 of the
present invention, the envisaged texture specified in
claim 1 was not obtained and, as a consequence, a
sufficient shape fixation property ($\Delta d/\sigma B$) was not
obtained. In steel F-10, since the annealing time was

35   outside the range specified in claim 24 of the present
invention, the envisaged texture specified in claim 1 was

not obtained and, as a consequence, a sufficient shape
fixation property ($\Delta d/\sigma B$) was not obtained.

Table 1

Steel	Chemical composition (in mass %)							Remarks
	C	Si	Mn	P	S	Al	Others	
A	0.041	0.02	0.26	0.012	0.0011	0.033	REM:0.0008	Invented steel
B	0.002	0.01	0.11	0.011	0.0070	0.044	Ti:0.057	Comparative steel
C	0.022	0.02	0.22	0.300	0.0015	0.012		Comparative steel
D	0.018	0.04	0.55	0.090	0.0400	0.033		Comparative steel
E	0.058	0.92	1.16	0.008	0.0009	0.041	Cu:0.48, B:0.0002	Invented steel
F	0.081	0.88	1.24	0.007	0.0008	0.031		Invented steel
G	0.049	0.91	1.27	0.006	0.0011	0.025	Cu:0.78, Ni:0.33	Invented steel
H	0.094	1.89	1.87	0.008	0.0007	0.024	Ti:0.071, Nb:0.022	Invented steel
I	0.060	1.05	1.16	0.007	0.0008	0.033	Mo:0.11	Invented steel
J	0.061	0.91	1.21	0.005	0.0011	0.030	V:0.02, Cr:0.08	Invented steel
K	0.055	1.21	1.10	0.008	0.0007	0.024	Zr:0.03	Invented steel
L	0.050	1.14	1.00	0.007	0.0009	0.031	Ca:0.0005	Invented steel

5

Underlined values are outside range of the invented
steel.

Table 2-1

Steel	Classification	Production conditions								Ratios of X-ray strength to random X-ray diffraction strength	
		Hot rolling process					Cold rolling and annealing processes				
		SRT (°C)	FT (°C)	Reduction ratio (%)	Lubrication	Coiling	Cold reduction ratio (%)	Annealing	Time (S)	Strength ratio 1	Strength ratio 2
A	Hot-rolled	1250	880	42	Not applied	O	-	-	-	5.8	0.7
B	Hot-rolled	1250	890	30	Applied	O	-	-	-	_1.3_	_6.1_
C	Hot-rolled	1200	880	30	Not applied	O	-	-	-	_0.8_	1.3
D	Hot-rolled	1200	880	30	Not applied	O	-	-	-	_1.2_	0.9
E	Hot-rolled	1150	870	42	Not applied	O	-	-	-	8.1	1.8
F-1	Hot-rolled	1200	870	42	Not applied	O	-	-	-	7.2	2.1
F-2	Hot-rolled	1200	870	42	Applied	O	-	-	-	8.3	1.4
F-3	Hot-rolled	1200	870	42	Applied	O	-	-	-	8.1	1.5
F-4	Hot-rolled	1200	970	42	Not applied	O	-	-	-	8.4	1.4
F-5	Hot-rolled	1300	950	_0_	Not applied	O	-	-	-	_1.8_	1.5
F-6	Hot-rolled	1300	970	_0_	Not applied	_×_	-	-	-	_1.8_	1.7
F-7	Cold-rolled	1200	860	-	Applied	-	65	O	90	4.2	2.3
F-8	Cold-rolled	1200	860	-	Applied	-	_80_	O	90	_2.8_	_4.2_
F-9	Cold-rolled	1200	860	-	Applied	-	65	_×_	90	_1.7_	2.6
F-10	Cold-rolled	1200	860	-	Applied	-	65	O	_2_	_1.8_	2.2
G	Hot-rolled	1150	870	71	Not applied	O	-	-	-	8.5	0.8
H	Hot-rolled	1250	870	30	Applied	O	-	-	-	8.7	0.9
I	Hot-rolled	1200	870	42	Not applied	O	-	-	-	5.7	2.0
J	Hot-rolled	1200	870	71	Not applied	O	-	-	-	5.9	2.1
K	Hot-rolled	1200	870	71	Not applied	O	-	-	-	7.8	1.0
L	Hot-rolled	1150	790	71	Not applied	O	-	-	-	11.0	1.4

Underlined values are outside range of the invented steel.

Table 2-2

Steel	Classification	Surface condition			Mechanical properties			Shape fixation property index Δd/σB* (mm/MPa)	Drawability index (D/d)	Remarks
		Ra (μm)	Lubrication coating	Friction coefficient	σY (MPa)	σB (MPa)	El (%)			
A	Hot-rolled	2.1	Applied	0.06	221	311	47	38	2.29	Invented steel
B	Hot-rolled	1.6	Not applied	0.22	161	281	56	41	1.86	Comparative steel
C	Hot-rolled	1.9	Applied	0.14	220	369	42	40	1.91	Comparative steel
D	Hot-rolled	2.0	Applied	0.17	195	306	44	44	1.97	Comparative steel
E	Hot-rolled	2.2	Applied	0.12	422	637	29	41	2.06	Invented steel
F-1	Hot-rolled	2.3	Applied	0.09	438	668	28	43	2.09	Invented steel
F-2	Hot-rolled	1.4	Applied	0.07	423	655	29	43	2.23	Invented steel
F-3	Hot-rolled	1.5	Not applied	0.23	419	649	29	69	1.80	Comparative steel
F-4	Hot-rolled	3.7	Applied	0.21	420	661	28	58	1.83	Comparative steel
F-5	Hot-rolled	2.0	Not applied	0.22	431	660	28	60	1.83	Comparative steel
F-6	Hot-rolled	2.3	Not applied	0.23	400	622	32	55	1.77	Comparative steel
F-7	Cold-rolled	0.5	Applied	0.08	418	671	28	36	2.11	Invented steel
F-8	Cold-rolled	0.6	Not applied	0.10	433	667	28	52	2.09	Comparative steel
F-9	Cold-rolled	0.6	Applied	0.07	552	721	20	55	2.17	Comparative steel
F-10	Cold-rolled	0.5	Not applied	0.11	570	710	21	61	2.09	Comparative steel
G	Hot-rolled	2.2	Applied	0.12	441	661	30	52	2.00	Invented steel
H	Hot-rolled	1.8	Applied	0.15	776	986	16	43	1.97	Invented steel
I	Hot-rolled	1.9	Applied	0.16	404	638	27	35	1.91	Invented steel
J	Hot-rolled	2.1	Applied	0.11	431	623	26	36	2.03	Invented steel
K	Hot-rolled	2.4	Applied	0.13	425	627	30	33	2.06	Invented steel
L	Hot-rolled	2.1	Applied	0.13	401	588	25	41	2.06	Invented steel

*: ×1000

Underlined values are outside range of the invented steel.

As has been explained in detail, the present
invention relates to a high-strength thin steel sheet
drawable and excellent in a shape fixation property and a
method of producing the steel sheet. By using the high-
5   strength thin steel sheet, a good drawability is realized
even with a steel sheet having a texture disadvantageous
for drawing work, and both a good shape fixation property
and a high drawability can be realized at the same time.
For this reason, the present invention is highly valuable
10   industrially.

Example 2
       A steel sheet according to any one of the items (8)
~ (10) is explained hereafter in more detail.
15   Steels A to L having the chemical components listed
in Table 3 were melted and refined in a converter, cast
continuously into slabs, reheated at the temperatures
shown in Table 4 and then rolled through rough rolling
and finish rolling into steel sheets 1.2 to 5.5 mm in
20   thickness, and then coiled. Note that the chemical
components in the table are expressed in terms of mass
percent. As shown in Tables 4-1, 4-2 and 4-3, some of
the steels were hot-rolled with lubrication. Steel L
underwent a descaling under the condition of an impact
25   pressure of 2.7 MPa and a flow rate of 0.001 l/cm^2 after
rough rolling. Further, some of the steel sheets
underwent pickling, cold rolling and heat treatment, as
shown in Table 2, after the hot rolling process. The
thickness of the cold-rolled steel sheets ranged from 0.7
30   to 2.3 mm. In addition, among the steels mentioned
above, steels G and A-8 underwent zinc plating.
       Table 4 shows the production conditions in detail.
In the table, "SRT" means the slab reheating temperature,
"FT" the finish rolling temperature at the final pass,
35   and "reduction ratio" the total reduction ratio in the
temperature range of the Ar_3 transformation temperature +
100°C or lower. Note that, in the case where a steel

sheet is cold-rolled after being hot-rolled, the
restriction is not necessary to be applied and,
therefore, each relevant space of "reduction ratio" is
filled with a horizontal bar, meaning "not applicable."

5   Further, "lubrication" indicates if or not lubrication is
applied in the temperature range of the Ar_3
transformation temperature + 100°C or lower. "CT" means
the coiling temperature. However, since it is not
necessary to restrict the coiling temperature as one of

10   the production conditions in the case of a cold-rolled
steel sheet, each relevant space is filled with a
horizontal bar, meaning "not applicable." Then, "cold
reduction ratio" means the total cold reduction ratio,
"ST" the heat treatment temperature, and "time" a heat

15   treatment time.

　　　　After completing the above production processes, a
composition having a lubricating effect was applied using
an electrostatic coating apparatus or a roll coater.

　　　　A hot-rolled steel sheet thus prepared was subjected

20   to a tensile test by forming a specimen into a No. 5 test
piece according to JIS Z 2201 and in accordance with the
test method specified in JIS Z 2241. The yield strength
(σY), tensile strength (σB) and breaking elongation (El)
are shown in Table 4. In the meantime, burring

25   workability (hole expansibility) was evaluated following
the hole expansion test method according to the Standard
of the Japan Iron and Steel Federation JFS T 1001-1996.
Table 4 shows the hole expansion ratio (λ).

　　　　An X-ray diffraction strength was measured by the

30   same method as employed in Example 1.

　　　　A shape fixation property was evaluated also in the
same manner as employed in Example 1.

　　　　Further, an arithmetic average of roughness Ra was
measured also by the same method as employed in Example

35   1.

　　　　Likewise, a friction coefficient was measured by the

same method as employed in Example 1.

Finally, a drawability index of a steel sheet was calculated in the same manner as employed in Example 1. A blank holding force of 10 kN was imposed in the case of steels B, 100 kN in the case of steel J, and 120 kN in the case of steels A, C, E, F, G, H, I and K.

It was understood that all the steel sheets having the friction coefficients within the range of the present invention showed a higher drawability index (D/d) than a steel sheet having the friction coefficient above the range of the present invention and the drawability index of any of the former steel sheets was 1.91 or more.

The examples according to the present invention are 12 steels, namely steels A-1, A-3, A-4, A-8, A-10, C, E, G, H, I, J, and L. In these examples, high-strength thin steel sheets drawable and excellent in a shape fixation property and a burring property are obtained: characterized in that, the steel sheets contain prescribed amounts of components, at least on a plane at the center of the thickness of any of the steel sheets, the average ratio of the X-ray strength in the orientation component group of {100}<011> to {223}<110> to random X-ray diffraction strength is 3 or more and the average ratio of the X-ray strength in three orientation components of {554}<225>, {111}<112> and {111}<110> to random X-ray diffraction strength is 3.5 or less, the arithmetic average of roughness Ra of at least one of its surfaces is 1 to 3.5 μm, and the surfaces of the steel sheet are covered with a composition having a lubricating effect; and further characterized in that at least one of the friction coefficients in the rolling direction and in the direction perpendicular to the rolling direction at 0 to 200°C is 0.05 to 0.2. As a consequence, in the evaluations by the methods according to the present invention, the indices of the shape fixation property of these steels were superior to those of conventional steels.

All the steel sheets in the tables other than those
mentioned above were outside the ranges of the present
invention for the following reasons.

In steel A-2, since the finish rolling termination
temperature (FT) and the total reduction ratio in the
temperature range of the Ar_3 transformation temperature +
100°C or lower were outside their respective ranges
specified in claim 21 of the present invention, the
envisaged texture specified in claim 1 was not obtained
and, as a consequence, a sufficient shape fixation
property ($\Delta d/\sigma B$) was not obtained. In steel A-5, since
a composition having a lubricating effect was not
applied, the envisaged friction coefficient specified in
claim 2 was not obtained and, as a consequence, a
sufficient drawability (D/d) was not obtained. In steel
A-6, since the arithmetic average of roughness Ra was
outside the range specified in claim 1 of the present
invention, the envisaged friction coefficient specified
in claim 2 was not obtained and, as a consequence, a
sufficient drawability (D/d) was not obtained. In steel
A-7, since the heat treatment temperature (ST) was
outside the range specified in any one of claim 28 of the
present invention, the envisaged texture specified in
claim 1 (should be any one of 3 to 5?) was not formed
and, as a consequence, a sufficient shape fixation
property ($\Delta d/\sigma B$) was not obtained. In steel A-9, since
the cold reduction ratio was outside the range specified
in any one of claim 28 of the present invention, the
envisaged texture specified in any one of claim 1 was not
obtained and, as a consequence, a sufficient shape
fixation property ($\Delta d/\sigma B$) was not obtained.

In steel B, the content of C was outside the range
specified in claim 8 of the present invention and, as a
consequence, a sufficient strength (σB) was not
obtained. In steel D, the content of Ti was outside the
range specified in any one of claim 8 of the present

invention and, as a consequence, neither a sufficient
strength (σB) nor a good shape fixation property (Δd/σB)
was obtained.   In steel F, the content of C was outside
the range specified in claim 8 of the present invention

5   and, as a consequence, a sufficient hole expansion ratio
(λ) was not obtained.   In steel I, the content of S was
outside the range specified in claim 8 of the present
invention and, as a consequence, neither a sufficient
hole expansion ratio (λ) nor a good elongation (El) was

10   obtained.   In steel K, the content of N was outside the
range specified in claim 8 of the present invention and,
as a consequence, neither a sufficient hole expansion
ratio (λ) nor a good elongation (El) was obtained.

Table 3

Steel	Chemical composition (in mass %)											Remarks
	C	Si	Mn	P	S	Al	N	Ti	Nb	Ti*	Others	
A	0.035	0.95	1.35	0.005	0.0008	0.031	0.0013	0.147	–	0.001	B:0.0005, Ca:0.0012	Invented steel
B	0.002	0.61	0.41	0.084	0.0010	0.015	0.0011	0.055	–	0.042		Comparative steel
C	0.055	0.61	1.45	0.005	0.0011	0.035	0.0012	0.181	0.095	0.004	REM:0.0008	Invented steel
D	0.016	0.02	0.20	0.010	0.0010	0.022	0.0017	0.025	–	-0.046		Comparative steel
E	0.025	0.88	0.95	0.008	0.0007	0.024	0.0016	0.110	0.027	0.017	Cu:1.15, Ni:0.48	Invented steel
F	0.120	0.11	1.12	0.018	0.0020	0.018	0.0026	0.021	–	-0.471		Comparative steel
G	0.033	1.61	0.42	0.007	0.0011	0.022	0.0018	0.133	0.036	0.012	Mo:0.08	Invented steel
H	0.027	0.18	2.43	0.007	0.0012	0.031	0.0015	0.126	–	0.011	Cr:0.5	Invented steel
I	0.037	0.89	1.41	0.003	0.0401	0.022	0.0022	0.121	0.031	-0.079		Comparative steel
J	0.024	0.91	0.45	0.011	0.0009	0.031	0.0019	0.125	–	0.021	Zr:0.03	Invented steel
K	0.038	0.88	1.65	0.007	0.0010	0.036	0.0061	0.132	–	-0.042		Comparative steel
L	0.030	0.88	0.71	0.005	0.0008	0.036	0.0021	0.119	0.045	0.014	V:0.032	Invented steel

Underlined values are outside range of the invented steel.

Table 4-1

Steel	Classification	Production conditions										
		Hot rolling process							Cold rolling and annealing processes			
		SRT (°C)	FT (°C)	Ar3+100 (°C)	Reduction ratio (%)	Lubrication	CT (°C)	TO (°C)	Cold reduction ratio (%)	ST (°C)	Ac3+10 (°C)	Time (S)
A-1	Hot-rolled	1230	890	915	42	Not applied	500	798	-	-	-	-
A-2	Hot-rolled	1230	920	915	0	Not applied	550	798	-	-	-	-
A-3	Hot-rolled	1230	890	915	42	Not applied	700	798	-	-	-	-
A-4	Hot-rolled	1230	890	915	42	Applied	500	798	-	-	-	-
A-5	Hot-rolled	1230	890	915	42	Applied	500	798	-	-	-	-
A-6	Hot-rolled	1230	890	915	42	Not applied	500	798	-	-	-	-
A-7	Cold-rolled	1230	880	-	-	Not applied	-	-	65	650	1049	90
A-8	Cold-rolled	1230	880	-	-	Applied	-	-	74	820	1049	90
A-9	Cold-rolled	1230	880	-	-	Applied	-	-	81	820	1049	60
A-10	Cold-rolled	1230	880	-	-	Not applied	-	-	74	820	1049	60
B	Hot-rolled	1180	890	992	71	Not applied	600	869	-	-	-	-
C	Hot-rolled	1180	860	892	42	Not applied	600	782	-	-	-	-
D	Hot-rolled	1180	890	990	71	Not applied	650	874	-	-	-	-
E	Hot-rolled	1180	880	943	71	Not applied	400	810	-	-	-	-
F	Hot-rolled	1180	850	886	42	Not applied	500	759	-	-	-	-
G	Hot-rolled	1180	910	1006	71	Applied	650	840	-	-	-	-
H	Hot-rolled	1180	800	812	30	Applied	550	739	-	-	-	-
I	Hot-rolled	1180	860	908	42	Applied	500	794	-	-	-	-
J	Hot-rolled	1180	890	989	71	Applied	600	851	-	-	-	-
K	Hot-rolled	1180	850	888	42	Applied	500	781	-	-	-	-
L	Hot-rolled	1180	900	966	71	Applied	650	833	-	-	-	-

Underlined values are outside range of the invented steel.

Table 4-2

Steel	Classification	Ratios of X-ray strength to random X-ray diffraction strength		Ra (μm)	Surface condition	
		Strength ratio 1	Strength ratio 2		Lubrication coating	Friction coefficient
A-1	Hot-rolled	6.8	1.9	2.2	Applied	0.08
A-2	Hot-rolled	_1.8_	1.7	2.3	_Not applied_	0.21
A-3	Hot-rolled	7.1	1.8	2.0	Applied	0.11
A-4	Hot-rolled	7.7	1.3	1.9	Applied	0.07
A-5	Hot-rolled	7.8	1.4	1.6	_Not applied_	0.21
A-6	Hot-rolled	7.8	1.3	_3.6_	Applied	0.22
A-7	Cold-rolled	_1.6_	2.5	0.5	_Not applied_	0.19
A-8	Cold-rolled	5.1	2.2	0.6	Applied	0.07
A-9	Cold-rolled	_2.7_	_4.3_	0.5	Applied	0.07
A-10	Cold-rolled	4.6	2.4	0.5	Applied	0.08
B	Hot-rolled	_1.2_	_6.6_	2.1	_Not applied_	0.23
C	Hot-rolled	5.9	2.1	2.3	Applied	0.12
D	Hot-rolled	_1.4_	_5.7_	2.3	Applied	0.10
E	Hot-rolled	7.2	2.1	2.0	Applied	0.08
F	Hot-rolled	_1.9_	_4.6_	2.4	_Not applied_	0.22
G	Hot-rolled	8.3	1.5	1.7	Applied	0.12
H	Hot-rolled	4.4	2.2	1.6	Applied	0.09
I	Hot-rolled	_1.8_	_4.6_	1.6	_Not applied_	0.21
J	Hot-rolled	_11.0_	1.6	1.9	Applied	0.08
K	Hot-rolled	_1.6_	_5.1_	2.0	_Not applied_	0.21
L	Hot-rolled	6.7	2.0	1.3	Applied	0.09

Underlined values are outside range of the invented steel.

Table 4-3

Steel	Classification	Mechanical properties				Shape fixation property index $\Delta d/\sigma B*$ (mm/MPa)	Drawability index d/D	Remarks
		σY (MPa)	σB (MPa)	El (%)	λ (%)			
A-1	Hot-rolled	588	779	22	94	42	2.10	Invented steel
A-2	Hot-rolled	603	811	20	106	68	1.86	Comparative steel
A-3	Hot-rolled	523	718	19	78	39	1.96	Invented steel
A-4	Hot-rolled	576	791	22	90	40	1.99	Invented steel
A-5	Hot-rolled	567	784	20	87	44	1.79	Comparative steel
A-6	Hot-rolled	581	795	21	86	42	1.82	Comparative steel
A-7	Cold-rolled	733	840	14	35	59	1.90	Comparative steel
A-8	Cold-rolled	594	800	20	78	45	2.19	Invented steel
A-9	Cold-rolled	586	790	20	76	63	2.01	Invented steel
A-10	Cold-rolled	559	810	19	94	44	2.15	Invented steel
B	Hot-rolled	293	427	40	138	55	1.88	Comparative steel
C	Hot-rolled	603	796	21	80	38	1.91	Invented steel
D	Hot-rolled	385	483	34	89	47	2.11	Comparative steel
E	Hot-rolled	580	785	23	106	39	2.20	Invented steel
F	Hot-rolled	571	769	18	35	49	1.82	Comparative steel
G	Hot-rolled	520	715	24	111	42	1.98	Invented steel
H	Hot-rolled	603	834	20	76	40	2.03	Invented steel
I	Hot-rolled	558	781	18	28	52	1.92	Comparative steel
J	Hot-rolled	480	634	26	134	44	2.14	Invented steel
K	Hot-rolled	590	814	17	41	53	1.93	Comparative steel
L	Hot-rolled	477	676	25	125	45	2.06	Invented steel

*:×1000

As has been explained in detail, the present
invention relates to a high-strength thin steel sheet
drawable and excellent in a shape fixation property and a
method of producing the steel sheet. By using the high-
strength thin steel sheet, a good drawability is realized
even with a steel sheet having a texture disadvantageous
for drawing work, and both a good shape fixation property
and a high drawability can be realized at the same time.
For this reason, the present invention is highly valuable
industrially.

CLAIMS

1.   A high-strength thin steel sheet drawable and excellent in a shape fixation property, characterized in that: at least on a plane at the center of the thickness of a steel sheet, the average ratio of the X-ray strength in the orientation component group of {100}<011> to {223}<110> to random X-ray diffraction strength is 3 or more and the average ratio of the X-ray strength in three orientation components of {554}<225>, {111}<112> and {111}<110> to random X-ray diffraction strength is 3.5 or less; the arithmetic average of the roughness Ra of at least one of the surfaces is 1 to 3.5 μm; and the surfaces of the steel sheet are covered with a composition having a lubricating effect.

2.   A high-strength thin steel sheet drawable and excellent in a shape fixation property according to claim 1, characterized in that the friction coefficient of the steel sheet surfaces at 0 to 200°C is 0.05 to 0.2.

3.   A high-strength thin steel sheet drawable and excellent in a shape fixation property according to claim 1 or 2, characterized in that the microstructure of the steel sheet is a compound structure containing ferrite as the phase accounting for the largest volume percentage and martensite mainly as the second phase.

4.   A high-strength thin steel sheet drawable and excellent in a shape fixation property according to claim 1 or 2, characterized in that the microstructure of the steel sheet is a compound structure containing retained austenite by 5 to 25% in terms of volume percentage and having the balance mainly consisting of ferrite and bainite.

5.   A high-strength thin steel sheet drawable and excellent in a shape fixation property according to claim 1 or 2, characterized in that the microstructure of the steel sheet is a compound structure containing bainite or ferrite and bainite as the phase accounting for the largest volume percentage.

6.   A high-strength thin steel sheet drawable and excellent in a shape fixation property according to any one of claims 1 to 5, characterized by containing, in mass,

5   C: 0.01 to 0.3%,

Si: 0.01 to 2%,

Mn: 0.05 to 3%,

P: 0.1% or less,

S: 0.01% or less, and

10   Al: 0.005 to 1%,

with the balance consisting of Fe and unavoidable impurities.

7.   A high-strength thin steel sheet drawable and excellent in a shape fixation property according to claim

15   6, characterized by further containing, in mass,

Ti: 0.05 to 0.5% and/or

Nb: 0.01 to 0.5%.

8.   A high-strength thin steel sheet drawable and excellent in a shape fixation property according to claim

20   1 or 2, characterized by containing, in mass,

C: 0.01 to 0.1%,

S: 0.03% or less,

N: 0.005% or less, and

Ti: 0.05 to 0.5%,

25   so as to satisfy the following expression:

Ti − (48/12)C − (48/14)N − (48/32)S ≧ 0%,

with the balance consisting of Fe and unavoidable impurities.

9.   A high-strength thin steel sheet drawable and

30   excellent in a shape fixation property according to claim 1 or 2, characterized in that the steel is a steel according to claim 8 further containing, in mass,

Nb: 0.01 to 0.5%, and

Ti, so as to satisfy the following

35   expression:

Ti + (48/93)Nb − (48/12)C − (48/14)N −

$(48/32)S \geqq 0\%$,

with the balance consisting of Fe and unavoidable impurities.

10. A high-strength thin steel sheet drawable and excellent in a shape fixation property, characterized in that the steel is a steel according to claim 8 or 9 further containing, in mass,

Si: 0.01 to 2%,

Mn: 0.05 to 3%,

P: 0.1% or less, and

Al: 0.005 to 1%.

11. A high-strength thin steel sheet drawable and excellent in a shape fixation property according to any one of claims 6 to 10, characterized by further containing, in mass,

B: 0.0002 to 0.002%.

12. A high-strength thin steel sheet drawable and excellent in a shape fixation property according to any one of claims 6 to 11, characterized by further containing, in mass,

Cu: 0.2 to 2%.

13. A high-strength thin steel sheet drawable and excellent in a shape fixation property according to any one of claims 6 to 12, characterized by further containing, in mass,

Ni: 0.1 to 1%.

14. A high-strength thin steel sheet drawable and excellent in a shape fixation property according to any one of claims 6 to 13, characterized by further containing, in mass,

Ca: 0.0005 to 0.002% and/or

REM: 0.0005 to 0.02%.

15. A high-strength thin steel sheet drawable and excellent in a shape fixation property according to any one of claims 6 to 14, characterized by further containing, in mass, one or more of

Mo: 0.05 to 1%,

V: 0.02 to 0.2%,

Cr: 0.01 to 1%, and

Zr: 0.02 to 0.2%.

16. A high-strength thin steel sheet drawable and
excellent in a shape fixation property according to any
one of claims 1 to 15, characterized by having a zinc
plating layer between the steel sheet and a composition
having a lubricating effect.

17. A method of producing a high-strength thin
steel sheet drawable and excellent in a shape fixation
property, characterized by: in a hot rolling process for
obtaining a high-strength thin steel sheet having the
chemical components according to any one of claims 6, 7
and 11 to 15, subjecting a slab having said chemical
components to rough rolling and, then, to finish rolling
at a total reduction ratio of 25% or more in terms of
steel sheet thickness in the temperature range of the Ar_3
transformation temperature + 100°C or lower; and,
thereafter, applying a composition having a lubricating
effect to the surfaces of the steel sheet.

18. A method of producing a high-strength thin
steel sheet drawable and excellent in a shape fixation
property according to claim 3, characterized by: in a hot
rolling process for obtaining a high-strength thin steel
sheet having the chemical components according to any one
of claims 6, 7 and 11 to 15, subjecting a slab having
said chemical components to rough rolling and, then, to
finish rolling at a total reduction ratio of 25% or more
in terms of steel sheet thickness in the temperature
range of the Ar_3 transformation temperature + 100°C or
lower, retaining the hot-rolled steel sheet thus produced
for 1 to 20 sec. in the temperature range from the Ar_1
transformation temperature to the Ar_3 transformation
temperature, then, cooling it at a cooling rate of
20°C/sec. or more, and coiling it at a coiling
temperature of 350°C or lower; and, thereafter, applying
a composition having a lubricating effect to the surfaces

of the steel sheet.

    19. A method of producing a high-strength thin steel sheet drawable and excellent in a shape fixation property according to claim 4, characterized by: in a hot rolling process for obtaining a high-strength thin steel sheet having the chemical components according to any one of claims 6, 7 and 11 to 15, subjecting a slab having said chemical components to rough rolling and, then, to finish rolling at a total reduction ratio of 25% or more in terms of steel sheet thickness in the temperature range of the Ar_3 transformation temperature + 100°C or lower, retaining the hot-rolled steel sheet thus produced for 1 to 20 sec. in the temperature range from the Ar_1 transformation temperature to the Ar_3 transformation temperature, then, cooling it at a cooling rate of 20°C/sec. or more, and coiling it at a coiling temperature in the range from over 350°C to below 450°C; and, thereafter, applying a composition having a lubricating effect to the surfaces of the steel sheet.

    20. A method of producing a high-strength thin steel sheet drawable and excellent in a shape fixation property according to claim 5, characterized by: in a hot rolling process for obtaining a high-strength thin steel sheet having the chemical components according to any one of claims 6, 7 and 11 to 15, subjecting a slab having said chemical components to rough rolling and, then, to finish rolling at a total reduction ratio of 25% or more in terms of steel sheet thickness in the temperature range of the Ar_3 transformation temperature + 100°C or lower, then, cooling it at a cooling rate of 20°C/sec. or more, and coiling it at a coiling temperature of 450°C or more; and, thereafter, applying a composition having a lubricating effect to the surfaces of the steel sheet.

    21. A method of producing a high-strength thin steel sheet drawable and excellent in a shape fixation property, characterized by: in a hot rolling process for obtaining a thin steel sheet having the chemical

components according to any one of claims 8 to 15,
subjecting a slab having said chemical components to
rough rolling and, then, to finish rolling at a total
reduction ratio of 25% or more in terms of steel sheet
5   thickness in the temperature range of the Ar_3
transformation temperature + 100°C or lower, and then,
cooling and coiling the steel sheet thus produced; and,
thereafter, applying a composition having a lubricating
effect.
10   22. A method of producing a high-strength thin
steel sheet drawable and excellent in a shape fixation
property according to any one of claims 17 to 21,
characterized by, in a hot rolling process, applying
lubrication rolling to the finish rolling after the rough
15   rolling.
            23. A method of producing a high-strength thin
steel sheet drawable and excellent in a shape fixation
property according to any one of claims 17 to 22,
characterized by, in a hot rolling process, applying
20   descaling after the completion of the rough rolling.
            24. A method of producing a high-strength thin
steel sheet drawable and excellent in a shape fixation
property, characterized by: in producing a high-strength
thin steel sheet having the chemical components according
25   to any one of claims 6, 7 and 11 to 15, subjecting a slab
having said chemical components to, sequentially, hot
rolling, pickling, cold rolling at a reduction ratio
below 80% in terms of steel sheet thickness, and then
applying a heat treatment comprising the processes of
30   retaining the cold-rolled steel sheet for 5 to 150 sec.
in the temperature range from the recovery temperature to
the Ac_3 transformation temperature + 100°C and then
cooling it; and, thereafter, applying a composition
having a lubricating effect to the surfaces of the steel
35   sheet.
            25. A method of producing a high-strength thin
steel sheet drawable and excellent in a shape fixation

property according to claim 3, characterized by: in
producing a high-strength thin steel sheet having the
chemical components according to any one of claims 6, 7
and 11 to 15, subjecting a slab having said chemical
5   components to, sequentially, hot rolling, pickling, cold
rolling at a reduction ratio below 80% in terms of steel
sheet thickness, and then applying a heat treatment
comprising the processes of retaining the cold-rolled
steel sheet for 5 to 150 sec. in the temperature range
10   from the Ac_1 transformation temperature to the Ac_3
transformation temperature + 100°C and then cooling it at
a cooling rate of 20°C/sec. or more to the temperature
range of 350°C or lower; and, thereafter, applying a
composition having a lubricating effect to the surfaces
15   of the steel sheet.
       26.   A method of producing a high-strength thin
steel sheet drawable and excellent in a shape fixation
property according to claim 4, characterized by: in
producing a high-strength thin steel sheet having the
20   chemical components according to any one of claims 6, 7
and 11 to 15, subjecting a slab having said chemical
components to, sequentially, hot rolling, pickling, cold
rolling at a reduction ratio below 80% in terms of steel
sheet thickness, and then applying a heat treatment
25   comprising the processes of retaining the cold-rolled
steel sheet for 5 to 150 sec. in the temperature range
from the Ac_1 transformation temperature to the Ac_3
transformation temperature + 100°C, cooling it at a
cooling rate of 20°C/sec. or more to the temperature
30   range from above 350°C to below 450°C, retaining it again
in this temperature range for 5 to 600 sec., and then
cooling it again at a cooling rate of 5°C/sec. or more to
the temperature range of 200°C or lower; and, thereafter,
applying a composition having a lubricating effect to the
35   surfaces of the steel sheet.
       27.   A method of producing a high-strength thin
steel sheet drawable and excellent in a shape fixation

property according to claim 5, characterized by: in producing a high-strength thin steel sheet having the chemical components according to any one of claims 6, 7 and 11 to 15, subjecting a slab having said chemical

5   components to, sequentially, hot rolling, pickling, cold rolling at a reduction ratio below 80% in terms of steel sheet thickness, and then applying a heat treatment comprising the processes of retaining the cold-rolled steel sheet for 5 to 150 sec. in the temperature range

10 from the Ac_1 transformation temperature to the Ac_3 transformation temperature + 100°C and then cooling it; and, thereafter, applying a composition having a lubricating effect to the surfaces of the steel sheet.

        28. A method of producing a high-strength thin

15 steel sheet drawable and excellent in a shape fixation property, characterized by: for producing a thin steel sheet having the chemical components according to any one of claims 8 to 15, subjecting a slab having said chemical components to, sequentially, hot rolling, pickling, cold

20 rolling at a reduction ratio below 80% in terms of steel sheet thickness, and then applying a heat treatment comprising the processes of retaining the cold-rolled steel sheet for 5 to 150 sec. in the temperature range from the recovery temperature to the Ac_3 transformation

25 temperature + 100°C and then cooling it; and, thereafter, applying a composition having a lubricating effect.

        29. A method of producing a high-strength thin steel sheet drawable and excellent in a shape fixation property according to any one of claims 17 to 23,

30 characterized by: galvanizing the surfaces of the steel sheet by dipping the steel sheet in a zinc plating bath after hot rolling; and, thereafter, applying a composition having a lubricating effect to the surfaces of the steel sheet.

35   30. A method of producing a high-strength thin steel sheet drawable and excellent in a shape fixation property according to any one of claims 24 to 28,

characterized by: galvanizing the surfaces of the steel
sheet by dipping the steel sheet in a zinc plating bath
after the completion of the heat treatment processes;
and, thereafter, applying a composition having a
5   lubricating effect to the surfaces of the steel sheet.
       31.   A method of producing a high-strength thin
steel sheet drawable and excellent in a shape fixation
property, characterized by: subjecting a steel sheet to
an alloying treatment after the galvanizing by dipping
10   the steel sheet in a zinc plating bath according to claim
29 or 30; and, thereafter, applying a composition having
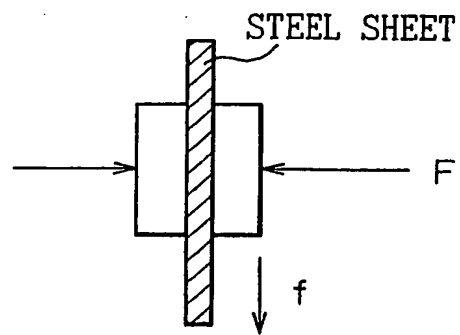a lubricating effect to the surfaces of the steel sheet.

Fig.1

Fig.2

STEEL SHEET

F

f
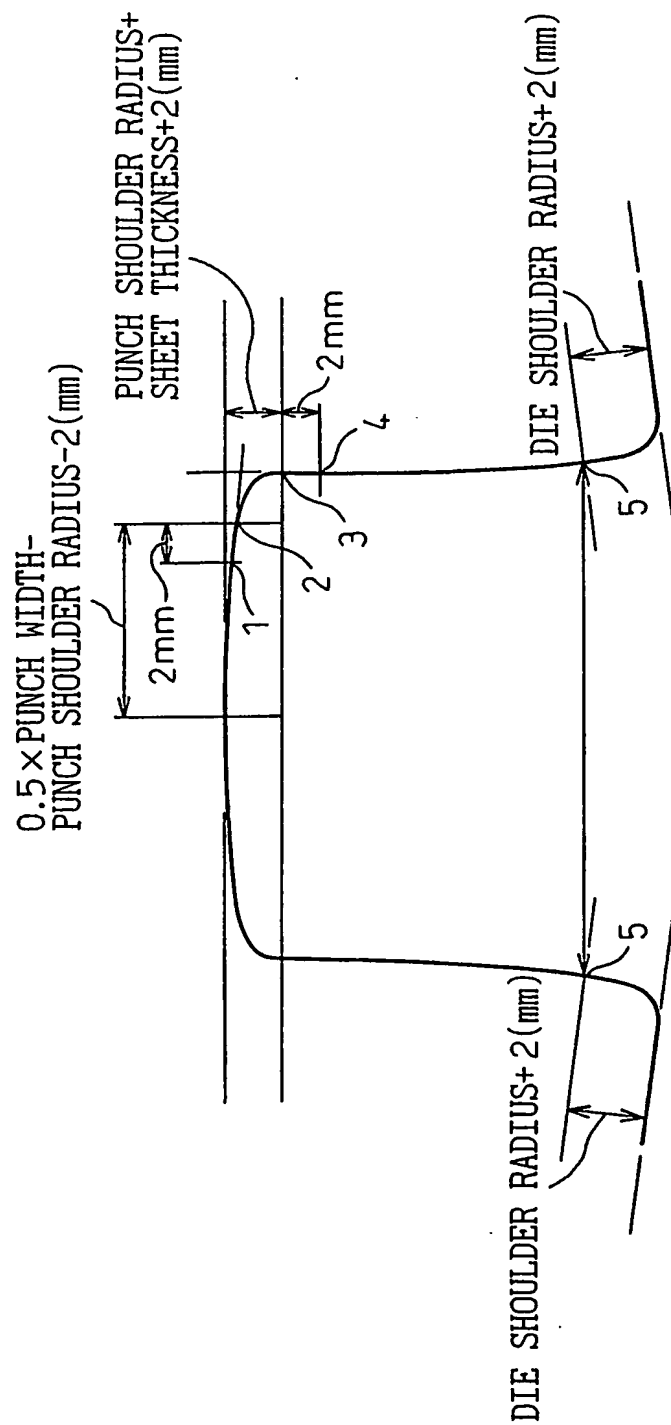
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7   C22C38/00   C21D8/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7   C22C   C21D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category°	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 572 748 A (SUGA MASATAKA ET AL) 25 February 1986 (1986-02-25) column 2, line 49 – line 59 column 5, line 19 – line 28 example 4; table I example 4A; table II ---	1-31
X	WO 97 39152 A (CENTRE RECH METALLURGIQUE ;SCHMITZ ALAIN (BE); HERMAN JEAN CLAUDE) 23 October 1997 (1997-10-23) page 1, line 29 – line 33 page 3, line 1 – line 10 page 4; example 2; tables I,II claims 1,4,5 ---	1-31

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[X] Further documents are listed in the continuation of box C.   [X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the International search	Date of mailing of the International search report
9 December 2002	27/12/2002

Name and mailing address of the ISA	Authorized officer
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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A,P	EP 1 201 780 A (NIPPON STEEL CORP) 2 May 2002 (2002-05-02) paragraph '0013! paragraph '0054! paragraph '0055! paragraph '0059! - paragraph '0060! page 12; examples A-C,G,K-Q; table 1 page 15; examples A,G-O; table 3 claims 1-14 ---	1-31
A	PATENT ABSTRACTS OF JAPAN vol. 1996, no. 05, 31 May 1996 (1996-05-31) -& JP 08 003679 A (NIPPON STEEL CORP), 9 January 1996 (1996-01-09) abstract example 5; table 1 example 5; table 2 ---	1-31
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